Proceedings, Missouri Ozark Forest Ecosystem Project (MOFEP)

2004 Annual Principal Investigators Meeting

David P. Gwaze, Editor

MOFEP

Missouri Ozark Forest Ecosystem Project

Runge Nature Center, Jefferson City

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Introductory Remarks

The Missouri Ozark Forest Ecosystem Project (MOFEP), a long-term, landscape-scale experiment to evaluate effects of even-aged, uneven-aged, and no-harvest management on the flora and fauna of oak ecosystems in southern Missouri, owes its success to hundreds of scientists and managers, and many institutions. I want to take this opportunity to thank all the people who have been involved with MOFEP. I want to thank the key collaborating institutions including the USDA Forest Service North Central Research Station, the Missouri Department of Natural Resources, the US Geological Survey, the Central Methodist College, and the Universities of Missouri-Columbia and St. Louis, Oklahoma and Toledo.

The objective of this meeting is to bring together MOFEP Principal Investigators to discuss key research findings and future plans. The meeting also provides an opportunity for principal investigators to get to know each other and to forge new partnerships. The meeting also comes at a time when we are revising the MOFEP strategic plan. The MOFEP strategic plan is an important document that spells out the direction and funding priorities for MOFEP. This meeting is thus timely as the presentations, discussions and the summary reports which you have all submitted will be used as a basis for developing the next 5-year MOFEP strategic plan.

As most of you are aware it's a requirement that all projects that we fund go through the Resource Science Division's internal review process. In addition, are approved by the MOFEP steering committee. The review process ensures that MDC funds quality studies that address critical needs in MOFEP. The project review process has three stages. Stage one is the one-page project concept which is due April 1, stage 2 is the Round I proposal due September 1 and stage 3 is the Round II proposal due November 15. The one-page concept is simply a presentation of a research idea. The Round I proposal focuses on objectives, justification, expected benefits, and evaluation approach. Round II is a revision of the Round I proposal and includes the operational details that fully describe the evaluation. You can get details of the review process from the MOFEP Coordinator.

One of the greatest challenges to MOFEP is continuity of current funding levels or the possibility of increased funding as we identify new research areas. While funding for MOFEP has been good over the years, one cannot predict the future with certainty. I want to stress that all Principal Investigators need to identify innovative ways to leverage the MDC support with outside grants. External funding will ensure that we do more research. Principal Investigators should take the opportunity to use the preliminary results from MOFEP to attract funding from other sources.

I cannot overemphasize the importance of submitting metadata and data for archiving. We are putting a high priority on data management because of the long-term, large scale and multidisciplinary nature of MOFEP. Well archived quality data will facilitate data exchange among scientists and will ensure that data collected today will be useful to scientists that come after us, even in 300 years. We have made submission of data and metadata a requirement in all proposals, and we have appointed a MOFEP database manager to show how serious we are about this issue. I hope you will continue to help us by submitting your data in a timely manner. If you have any problems submitting data or suggestions for improving the web site please contact the MOFEP database manager.

Finally, there have been a few changes to the MOFEP administrative staff. We say farewell to Eric Kurzejeski, who was the MOFEP Coordinator. Eric accepted the position of Chief, Outreach and Education Division, Missouri Department of Conservation. Eric will still be available to assist with MOFEP issues. Vicki Heidy who replaced Eric will provide administrative oversight for MOFEP. The new MOFEP Coordinator is David Gwaze, who is also the Chair of the MOFEP Steering Committee. Tom Treiman relinquished his duties as the MOFEP database manager, and his position was filled by Julie Fleming. Please give Vicki, David and Julie all the support they need in their new roles, and lets wish Eric the very best in his new job.

Have a great meeting!

Larry Vangilder
Chief
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Resource Science Division
Missouri Department of Conservation

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Overstory Vegetation

Project Title: Overstory vegetation following even-aged, uneven-aged and no-harvest treatments on the Missouri Ozark Forest Ecosystem Project sites

Team Members: John Kabrick, Steve Shifley, David Larsen and Randy Jensen

Project Goals:
1. To quantify effects of even-aged, uneven-aged, and no-harvest management systems and on forest structure and reproduction.

2. To quantify forest composition, regeneration, succession, and site quality in relation to environment (e.g., site factors, elts, soils).

3. To quantify factors governing the growth and dynamics of individual trees and their competitors in stands under different management systems.

4. To use MOFEP data in part or in its entirety to examine important issues in or problems affecting Missouri Ozark forests (e.g., oak decline/red oak borer, evaluating the effectiveness of uneven-aged silviculture for perpetuating oak forests, historic role of disturbance, the ecology of Ozark forests, concern about impending gypsy moth infestation).

Key Findings:
The environment at MOFEP is much more heterogeneous than once believed (see Meinert and others, 1997; Kabrick and others, 2000; Nigh and others, 2000).

MOFEP sites are dominated by five woody species; white oaks, scarlet oaks, black oaks, shortleaf pines, and post oaks comprise more than 80% of the stocking. The remaining 20% includes blackgum, hickories, red maple, and dogwood (see Kabrick and others, 1997; Kabrick and others, 2002).

Productivity is much more closely allied with environmental variables than is species composition (see Kabrick and others, 1999; Kabrick and others, 2002).

In the absence of timber harvesting or stand-replacing disturbances, overstory species composition is changing rapidly. Most notably are decreases in the abundance of scarlet oaks and black oaks due to high mortality and low recruitment and increases in the abundance of white oaks due to low mortality and high recruitment (see Kabrick and Jensen, 1999; Kabrick and others, 2000; Kabrick and others, 2002).

For a given diameter and species, tree mortality decreased with improved crown position, but mortality rates increased sharply with increasing diameter for dominant and codominant scarlet and black oaks. Mortality rates for dominant and codominant white and post oaks were stable or increased only slightly with increasing tree diameter. Mortality of black and scarlet oaks exceeded 20 percent per decade for dominant and codominant trees > 8 inches dbh. In contrast, mortality of white oaks and post oaks in the same canopy and size classes was approximately 2 percent (see Kabrick and others, 2004).

Timber harvesting has caused obvious changes to forest structure in treated stands. However, it is too soon to know if the different management methods (i.e., even-aged, uneven-aged, and no-harvest) cause differences in reproduction composition or recruitment (see Kabrick and others, 2000).

Challenges Faced:
The overstory vegetation sample design is very good for quantifying overstory composition, growth, and mortality at the site, stand, and plot scales. However, the MOFEP design was sometimes insufficient to answer questions about how forest composition, succession, and productivity are related to environmental variables or questions where spatial information was critical.

New Research:
1. Oak decline-related research. We are presently examining the role of environmental variables on increasing the threat of oak decline and looking for other stand- or tree-level characteristics that improve the ability to forecast decline and/or mortality.

2. Oak regeneration research. Now that ten years have passed since harvests, we can now evaluate oak regeneration success by harvest type. Specifically, we want to determine if oak regeneration differs among stands that were clearcut, harvested with single-tree selection, or harvested with a combination of single-tree and group selection methods. We also want to know if there are interactions with the kind of harvesting and measures of site quality (i.e., site index, elt, soil type).

Scientific Outputs:
Invited Presentations
Kabrick, J.M. 1997. Soils, geology, landform and vegetation interactions on the Missouri Ozark Forest Ecosystem Project sites. Missouri Department of Conservation Annual Resource Managers Conference, Van Buren, MO, January 22, 1997.

Kabrick, J.M. 2000. Sustaining forest soil productivity in the Missouri Ozarks. Missouri Cooperative Soil Survey Work Planning Conference, University of Missouri, Columbia, MO, May 24, 2000.

Kabrick, J.M., J.K. Grabner, D. Meinert, D.R. Larsen, and R.D. Hammer. 2002. Soil-landscape information needed for understanding the ecology and management of forest vegetation in the Missouri Ozarks. Missouri Natural Resources Conference, Osage Beach, MO, February 1, 2002; Missouri Cooperative Soil Survey Work Planning Conference, University of Missouri, Columbia, MO, June 18, 2002. (http://www.mo.nrcs.usda.gov/soils/soilsym/soils_sym.htm)

Offered Presentations

Kabrick, J.M., D.R. Larsen, and R.D. Hammer. 1995. Occurrence likelihood and relative abundance of oaks among Missouri Ozark soil-landscape units. Missouri Ozark Forest Ecosystem Project principal investigator's meeting, Jefferson City, MO. November 6, 1995.

Kabrick, J.M., and D.R. Larsen. 1996. Vegetation relationships in Ozark landscapes. Annual Forestry, Fisheries and Wildlife Conference, Osage Beach, MO. February 2, 1996.

Kabrick, J.M., D.R. Larsen and S. R. Shifley. 1997. Analysis of pretreatment MOFEP woody vegetation and environmental data: Evaluation for compartment, block and treatment trends in species counts, density, diameter and basal area. Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research, St. Louis, MO. June 3-5, 1997. (Publication)

Meinert, D., T. Nigh and J. Kabrick. 1997. Landforms, geology and soils of the MOFEP study area. Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research, St. Louis, MO. June 3-5, 1997. (Publication)

Brookshire, B.L., J.M. Kabrick, D.R. Larsen and S.R. Shifley. 1997. Soils, geology, landform, and vegetation interactions in the Missouri Ozarks. Ecological Society of America annual meeting, Albuquerque, NM. August 1997. (Abstract)

Kabrick, J.M., T. Nigh, D. Meinert, and D.R. Larsen. 1998. Woody vegetation abundance and site index related to ecological units of the lower Ozarks: Implications for developing ecological landtypes. Missouri Natural Resources Conference, Osage Beach, MO, February 18-20, 1998.

Kabrick, J.M., D. Meinert, R.D. Hammer, and D.R. Larsen. 1998. Vegetation-soil relationships in the Missouri Ozarks. Presented at the North Central Regional Cooperative Soil Survey Conference, Columbia, MO, June 15-16, 1998.

Nigh, T.A., J.M. Kabrick, J.K. Grabner, and B.L. Brookshire. 1998. Ecological classification in the Missouri Ozarks. Ecological Society of America annual meeting, Baltimore, MD. August 2-6, 1998. (Poster/Abstract).

Kabrick, J.M., and R.G. Jensen. 1999. Factors affecting tree growth rates in Ozark forests. Missouri Natural Resources Conference, Osage Beach, MO. February 1-3, 1999.

Kabrick, J.M., R.G. Jensen, S.L. Sheriff, J.K. Grabner, and W.K. Gram. 1999. The Missouri Ozark Forest Ecosystem Project. Symposium on Ecosystem Management Research in the Ouachita and Ozark Mountains, Hot Springs, Arkansas. October 26-27, 1999.

Kabrick, J.M., R.G. Jensen, S.R. Shifley, and D.R. Larsen. 2000. Woody vegetation following even-aged, uneven-aged, and no-harvest treatments on the Missouri Ozark Forest Ecosystem Project Sites. Second Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment Results of the Landscape Experiment, St. Louis, MO. October 17-18, 2000. (Publication)

Guyette, R., and J.M. Kabrick. 2000. The legacy and continuity of forest disturbance, succession, and species at the MOFEP sites. Second Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment Results of the Landscape Experiment, St. Louis, MO. October 17-18, 2000. (Publication)

Jensen, R.G., J.M. Kabrick, and E.K. Zenner. 2000. Tree cavity estimation and verification in the Missouri Ozarks. Second Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment Results of the Landscape Experiment, St. Louis, MO. October 17-18, 2000. (Publication)

Darrow, D., J.M. Kabrick, J. Grabner, and R. Jensen. 2000. Missouri Ozark Forest Ecosystem Project: Aiming for adaptive Management. Ecological Society of America annual meeting, Snowbird, UT. August 6-10, 2000. (Abstract)

Grabner, J.K., T.A. Nigh, J.M.Kabrick, and C.E. Buck. 2000. Ecological land classification in Missouri. Wildlife Society 7th Annual Conference Program and Abstracts, Nashville, TN, September 2000. (Abstract)

Kabrick, J.M., D. Meinert, D.R. Larsen, and R.D. Hammer. 2000. Relationships between the soil-landscape and woody vegetation in Missouri Ozark Forests. Soil Science Society of America annual meeting, Minneapolis, MN November 5-9, 2000. (Poster/Abstract)

Bruhn, J.N., R.P. Guyette, J.D. Mihail, and J.M. Kabrick. 2002. Armillaria species and the legacy of forest disturbance in Ozark Highlands landscapes of the central U.S.A. Seventh International Mycological Congress, Oslo, Norway. August 11-17, 2002. (Abstract)

Kabrick, J.M., S.R. Shifley, R.G. Jensen, D.R. Larsen, and J.K Grabner. 2002. Oak forest composition, site index patterns, and dynamics in relation to site factors in the southeastern Missouri Ozarks. Upland Oak Ecology: The history, current conditions, and sustainability, Fayetteville, AR. Oct 7-10, 2002. (Publication).

Guyette, R. P., R.M. Muzika, J.M. Kabrick, and M.C. Stambaugh. 2002. A perspective on Quercus life history characteristics and forest disturbance. Upland Oak Ecology: The history, current conditions, and sustainability, Fayetteville, AR. Oct 7-10, 2002. (Poster/Publication).

Kabrick, J.M., S.R. Shifley (speaker), R.G. Jensen, Z. Fan, and D.R. Larsen. 2004. Factors Associated With Oak Mortality In Missouri Ozark Forests. 14th Central Hardwood Forest Conference, The Ohio State University, Wooster, OH, March 17-19, 2004 (Publication).

Kabrick, J.M., R.B. Renken, E.W. Kurzejeski, R.G. Jensen (speaker), W.K. Gram, R.L. Clawson, P.A. Porneluzi, J. Faaborg, D.K. Fantz, J.K. Grabner, and M. Johanson. 2004. The Missouri Ozark Forest Ecosystem Project: Findings From Ten Years Of Evaluating Management Effects On Forest Systems. 14th Central Hardwood Forest Conference, The Ohio State University, Wooster, OH, March 17-19, 2004 (Publication).

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Kabrick, J.M., D.R. Larsen and S. R. Shifley. 1997. Analysis of pretreatment MOFEP woody vegetation and environmental data: Evaluation for compartment, block and treatment trends in species counts, density, diameter and basal area. pp 150-168. In: Brookshire, Brian L.; Shifley, Stephen R.; eds. Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. (refereed).

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Kabrick, J., D. Meinert, T. Nigh, and B.J. Gorlinsky. 2000. Physical environment of the Missouri Ozark Forest Ecosystem Project sites. pp 41-70. In: Shifley, Stephen R.; Brookshire, Brian L.; eds. Missouri Ozark Forest Ecosystem Project Site History, Soils, Landforms, Woody and Herbaceous Vegetation, Down Wood, and Inventory Methods for the Landscape Experiment. Gen. Tech. Rep. NC-208. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. (refereed).

Nigh, T., Buck, C., Grabner, J., Kabrick, J., and D. Meinert. 2000. An ecological classification system for the Current River Hills Subsection. Missouri Department of Conservation.

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Guyette, R. P., R.M. Muzika, J.M. Kabrick, and M.C. Stambaugh. 2004. A perspective on Quercus life history characteristics and forest disturbance. pp. 138-142. In: Spetich, Martin A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 311p.

Kabrick, J.M., S.R. Shifley, R.G. Jensen, D.R. Larsen, and J.K Grabner. 2004. Oak forest composition, site index patterns, and dynamics in relation to site factors in the southeastern Missouri Ozarks. pp. 94-101. In: Spetich, Martin A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 311p.

Kabrick, J.M., S.R. Shifley, R. G. Jensen, Z. Fan, and David R. Larsen. 2004. Factors associated with oak mortality in Missouri Ozark Forests. Pp 27-35. In: Yaussy, Daniel A.; Hix, David M.; Long, Robert P.; Goebel, P. Charles, eds. 2004. Proceedings. 14th Central Hardwood Forest Conference; 2004 March 16-19; Wooster, OH. Gen. Tech. Rep. NE-316. Newtown Square, PA:

U.S. Department of Agriculture. Forest Service. Northeastern Research Station. 539 p. [CD-ROM]. (Refereed)

Kabrick, J.M., R.B. Renken, E.W. Kurzejeski, R.G. Jensen, W.K. Gram, R.L. Clawson, P.A. Porneluzi, J. Faaborg, D.K. Fantz, J.K. Grabner, and M. Johanson. 2004. The Missouri Ozark Forest Ecosystem Project: Findings from ten years of evaluating management effects on forest systems. Pp 484-496. In: Yaussy, Daniel A.; Hix, David M.; Long, Robert P.; Goebel, P. Charles, eds. 2004. Proceedings. 14th Central Hardwood Forest Conference; 2004 March 16-19; Wooster, OH. Gen. Tech. Rep. NE-316. Newtown Square, PA: U.S. Department of Agriculture. Forest Service. Northeastern Research Station. 539 p. [CD-ROM]. (Refereed)

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Canopy Mapping

Project Title: Competitive response of woody vegetation to Missouri Ozark Forest Ecosystem Project Treatments

Team Members: David Larsen, Mark Johanson, Randy Jensen

Project Objectives:
Canopy mapped data sets are relativity rare and repeat measure canopy mapped data are even rarer. There are probably less than 20 data sets of good quality anywhere in the world. The project objectives are to:

1. Determine how MOFEP treatments affect understory regeneration abundance? This will be compared to previous work on Pioneer Forest.

   Expectation: The abundance of all species will increase with decreasing overstory density. The relationship is expected to be non-linear and vary by species.

2. Determine how overstory density affects recruitment of different sizes and species of trees into the overstory?

   Expectation: The growth rates of understory tree will increase as overstory density decreases. The relationship is expected to be non-linear and vary by species.

3. Determine the rate of overstory tree crown filling of available growing space after a partial removal of overstory trees?

   Expectation: The growth rate of the overstory canopy will be proportional to the height growth for that species and site index, modified by relative crown area surface area, and the relative crown width in relation to maximum crown width for that species. The relationship is expected to be non-linear and other co-variates may also have an effect.

Progress:
Canopy Mapping plots were established in 1994-95, re-measured in 1998-99 and are being re-measure in 2004-05 making the value of this dataset outstanding. These plots are found in all three MOFEP treatments and on the two major ELTs (17, 18). With the re-measurement of the plots in the 2004-2005 dormant season, we will now have a ten year dataset with three measurements of these plots. In stand dynamics, the longer the time sequence the better able the data are to informing us about the dynamics in the life of these plants. After the 2004-2005 season is the first time that these data can be analyzed and expected to provide useful result. A proposal to hire a student to work on this dataset has been developed and is being reviewed by MDC.

Benefits:
This study should enable specific management guidelines for the levels of potential overstory stocking when understory development is desired. It can also specify the overstory crown

response to the thinning of the overstory. It will additionally be able to describe the understory mortality patterns as the understory competitively sorts itself. All these are information needed to write relevant management guidelines for treatments that are expected to be successful in repeated applications.

A scientific question that can be addressed is the general assumption that seedlings have similar mortality rates. If this were true one could determine the future dominant forest by counting the number of seedling by species present in the current stand. Different tree species, however, differ in their rate of mortality. This means that a stand can be dominated by one species in the early stage of stand development and later that same species can be eliminated from the stand. While some of the dynamics can be explained there are threshold beyond which the outcomes differ. These thresholds are not well identified. This project offers the potential to identify some of the development pathways and the like outcomes.

Ground Flora

Project Title: Changes in ground flora following timber harvests on the Missouri Ozark Forest Ecosystem Project

Team Members: Randy Jensen, Jennifer Grabner, Eric Zenner, John Kabrick, and David Larsen, JeriLynn Peck.

Project Goals:
1. Determine pre-treatment differences among sites, treatment classes, and replication blocks with respect to ground flora species composition, plot diversity, and plot richness at the site, block, and treatment levels.

2. Detect patterns in the ground flora data in relation to environmental conditions both within and among sites.

3. Document changes in ground flora vegetation following even-age, uneven-age, and no-harvest management.

Key Findings:
Pre-treatment
Approximately 530 different species, including 275 genera in 85 families, were identified. More than half of the species occurred on less than 10% of the 648 vegetation plots (10,368 1m^2 quadrats).

Plots averaged high species diversity but there were plots with low and high species richness and species diversity within all sites.

Differences in ground flora species composition and abundance, plot richness, and plot diversity were highly correlated with differences in geology, landform, and soils, both within and among sites.

Post-treatment
Mean species richness by plot decreased significantly on no-harvest sites but increased slightly on both even-age and uneven-age sites (fig. 1).

Total percent ground cover increased on all sites and treatments but harvested sites increased more than no-harvest sites (fig. 2).

Annual / biennial species increased on all management treatments but increased the most on even-age management sites. The post-treatment percent relative cover of these species was 1% or less across all sites, however.

The relative cover (%) of woody vines increased slightly on all sites but increased the most on the even-age and uneven-age management sites.

The relative abundance of legumes decreased significantly on harvested sites but increased slightly on no-harvest sites.

Scientific outputs:

Grabner, Jennifer K. and Zenner, Eric K. 2002. Changes in ground layer vegetation following timber harvests on the Missouri Ozark Forest Ecosystem Project). p. 66-83. _In: S. R. Shifley and J. M. Kabrick (eds.) Proceedings of the second Missouri Ozark Forest Ecosystem Symposium: post treatment results of the landscape experiment. October 17-20, 2000; St. Louis, MO. General Technical Report NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 228p. (presentation and refereed publication).

Grabner, Jennifer K. 2000. Ground Layer Vegetation in the Missouri Ozark Forest Ecosystem Project: Pre-treatment Species Composition, Richness, and Diversity. pp 107-123. In: Shifley, Stephen R.; Brookshire, Brian L.; eds. Missouri Ozark Forest Ecosystem Project Site History, Soils, Landforms, Woody and Herbaceous Vegetation, Down Wood, and Inventory Methods for the Landscape Experiment. Gen. Tech. Rep. NC-208. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. (refereed publication).

Grabner, Jennifer K., Larsen, David R., and Kabrick, John M. 1997. An analysis of MOFEP ground flora: pre-treatment conditions. In: Brookshire, B. L.; Shifley, S. R. (eds.). Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research. 1997 June 3-5; St. Louis, MO. General Technical Report. NC-193. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, MN. 378p. (presentation and refereed publication).

Zenner, E.K., J.M. Kabrick, J.K. Grabner and R.J. Jensen. (in press). Are landscape-level effects more than the sum of stand-level effects in the Missouri Ozark Forest Ecosystem Project (MOFEP)? IUFRO workshop on Balancing Ecosystem Values – innovative experiments for sustainable forestry. Portland, OR. August 15-22, 2004.

Zenner, E.K., J..L. Peck, J.K. Grabner, J.M. Kabrick, and R.J. Jensen. (in preparation). Responses of ground flora to a gradient of harvest intensity in the Missouri Ozarks. Forest Science.

MOFEP Ground Flora data used:

Sasseen, Alicia N. 2003 (Rose-Marie Muzika advisor) - Using Ecological Landtype phase (ELTp) to evaluate the effect of management on Missouri Ozark vegetation. Unpublished Master Thesis. University of Missouri. Columbia MO.

Grabner, Jennifer 2002 (David R. Larsen advisor) - Patterns in upland forest vegetation in relation to geology, topography, and soils: an approach to ecological land classification in the Southeast Missouri Ozarks. Unpublished Masters Thesis. University of Missouri. Columbia MO.

Hooten, Mevin B. 2001 (David R. Larsen advisor) - Modeling the distribution of ground flora on large spatial domains in the Missouri Ozarks. Unpublished Masters Thesis. University of Missouri. Columbia MO.

Becker, Cindy E. 1999 (Stephen G. Pallardy advisor) - Multifactor classification of intermittent creeks in the Southeast Missouri Ozarks. Unpublished Masters Thesis. University of Missouri. Columbia MO.

Larsen, D. R. and P. L. Speckman. 2004. Multivariate regression trees or analysis of abundance data. Biometrics 60:543-549.

Figure 1. The mean differences between post-treatment and pre-treatment species richness per plot by treatment; and the difference between cutting types within even-age and uneven-age sites. Error bars are 95 percent confidence intervals.

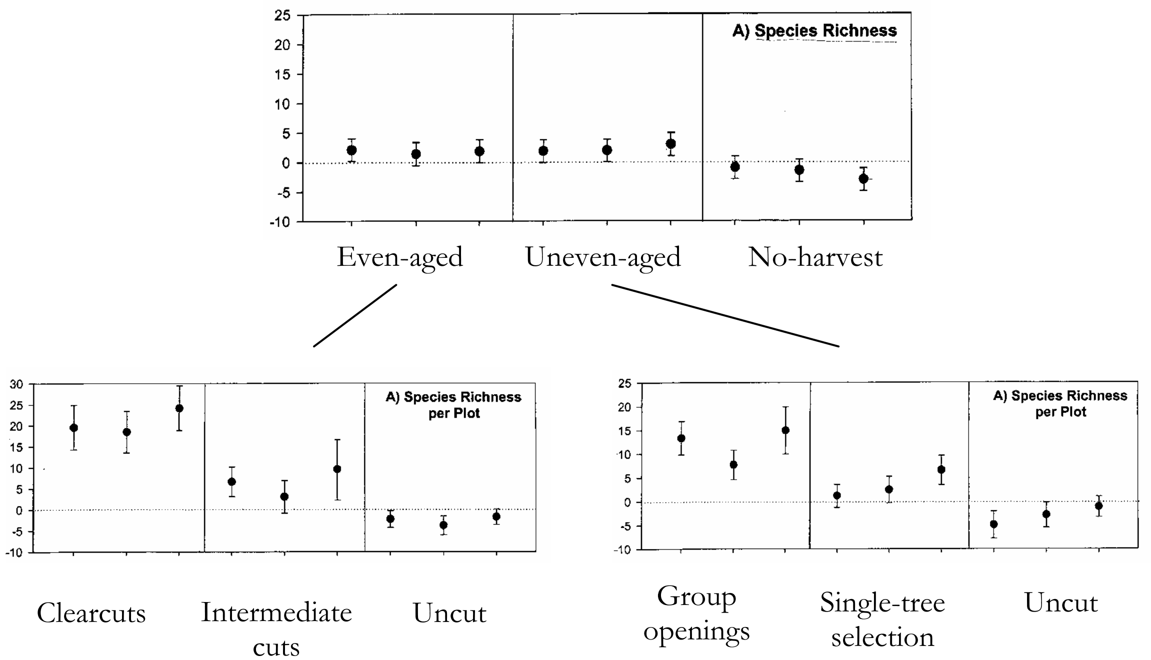
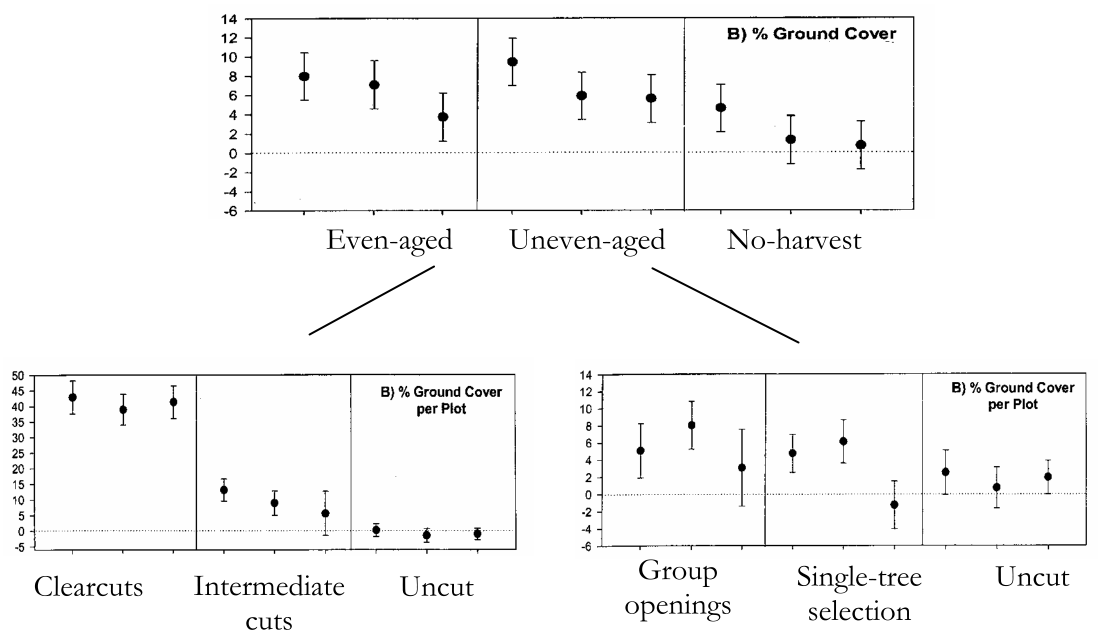


Figure 2. The mean differences between post-treatment and pre-treatment percent ground cover per plot by treatment; and, the difference between cutting types within even-age and uneven-age sites. Error bars are 95 percent confidence intervals.



Forest History

Project Title: The forest history of the Missouri Ozark Forest Ecosystem Project

Team Members: Richard P. Guyette, Michael Stambaugh, Timothy Nigh, David Gwaze

Project Summary:
This project's work and goals centered on the communication, data acquisition, and publication of forest history, fire history, forest ecology, and species associations at the MOFEP sites. Communication was facilitated by presentations and MOFEP interactions. We gave 11 presentations and poster papers at many different difference conferences from the Ecological Society of America to the Missouri Natural Resources Conference. Project fire history data for all MOFEP sites was submitted and placed on the MOFEP web site and selected site data is also available via the International Multiproxy Paleofire Data Base. Tree ring data (shortleaf pine ring-width chronologies) were developed, submitted and placed in the MOFEP data base. More than 22 papers have been published in journals and proceedings. Requests for these publications have come from all continents. A number of unpublished manuscripts have also been submitted to the Missouri Department of Conservation.

Dynamics of an anthropogenic fire regime (Guyette, Muzika, and Dey):
Human beings have had an impact on the forests and wildlife of the MOFEP sites for thousands of years, long before today's flora and fauna invaded the MOFEP sites during the post-glacial climate of the last several thousand years. The floral and faunal communities of the MOFEP sites have co-evolved with human as well as natural disturbances. Emphasis is given to the last 300 years because of quantitative data provided by the tree-ring record, the availability of historical documents, and the importance of this period in forming the current ecosystem. Human impacts on the MOFEP sites have been greatest in more recent times because of a growing human population at both local and global scales.

Long-term growth and climate response of shortleaf pine (Stambaugh and Guyette):
Shortleaf pine (*Pinus echinata*) is one of the most of important conifers in the Central Hardwood region both ecologically and economically. In the Ozark Highlands of Missouri and Arkansas, the presence of shortleaf pine provides an important conifer component in otherwise hardwood dominated forest types. Regional forest health issues such as oak decline and red oak borer as well as pine restoration efforts have increased interest in the species and the management of oak-pine forest types. Using tree-ring data collected at the Missouri Ozark Forest Ecosystem Project (MOFEP), we provide a long-term perspective of shortleaf pine growth, climate response, and regeneration. Tree-ring data from shortleaf pine remnants and cores of live trees illustrate the temporal variability in growth of shortleaf pine over the past 386 years. We developed a climate response function based on instrumental climate data from a 70 year period (1931-2001). Variation in shortleaf pine ring-width was most strongly correlated with growing year Palmer Drought Severity Index (PDSI) months, extreme minimum winter temperatures, and previous fall season PDSI ($r^2 = 0.43$, $p < 0.0001$). Further analysis of the relationship between tree-ring indices and PDSI suggest that the correlation was higher in the early half of the 20th century than the latter half. Late winter (January and February) may be becoming increasingly important in determining shortleaf pine growth. Spectral estimates of the tree-ring chronology suggest that

shortleaf pine growth has a near 21 year periodic variation that is likely an influence of larger scale climatic cycles. Comparisons between growth of shortleaf pine in three age classes both pre- and post 1880 show that the species' growth rate was significantly greater during the 20^{th} century than for the two prior centuries.

*The legacy of forest disturbance, succession, and species (*Guyette and Kabrick):
Scientific literature on the distribution, continuity, and legacy of disturbance regimes in Ozark ecosystems is sparse (Batek et al. 1999, Guyette and Cutter, 1997). Knowledge of these disturbance regimes is valuable in understanding our changing forest ecosystems and in applying silvicultural prescriptions. Tree ring data provide a perspective on the frequency and spatial distribution of disturbance events in Ozark forests which can be related to ecosystem dynamics. Here, we generate a significant correlation matrix of diverse variables from a central hypothesis, that MOFEP sites and species are distributed along a gradient of forest succession induced by disturbances from the long-term interactions of humans and mitigated by topographic roughness. Abrupt ring-width reductions in shortleaf pine (*Pinus echinata*), fire frequency, and historical data are used to determine the frequency and magnitude of disturbance events. Mean growth setback return intervals in shortleaf pine at the MOFEP sites varied by a factor of more than 4 while mean diameter loss due to growth setbacks varied by a factor of more than 10. Disturbance variables are significantly correlated with topographic roughness, forest bird territory density, lizard and skink captures, blueberry fruit abundance, *Armillaria spp.* abundance, and three indices of forest succession derived from over story tree species, oak over story species, and tree species ground flora. These three indices of forest succession, based solely on shade tolerance, are significantly correlated with the mean number of overstory tree species, the density of forest bird territories, lizard and skink captures, topographic roughness, blueberry fruit abundance, and the abundance of two *Armillaria spp.* Disturbance history, species distributions, and tree species diversity at the MOFEP sites support the hypothesis that these sites lie along a successional gradient induced by the long-term interactions of fire, humans, and topographic roughness. The correlation matrix of diverse variables in this ecosystem supports the argument that long-term disturbance regimes and successional sequences are major factors effecting species and structure in Ozarks forests.

In the heart of roughness (Guyette and Stambaugh)
Landscapes in the Ozarks vary greatly with respect to surface topography. Some are very rough and steep, while others are rolling and smooth. Landscape roughness or *topographic roughness* mitigates and slows the movement and propagation of humans, fire, and commerce across the land (Guyette and Dey 2000). The degree of landscape roughness can be quantified as indices of topographic roughness, calculated here as the ratio of the surface of the earth measured with large and small surfaces. Maps of indices of topographic roughness indicate that Pioneer Forest is one of the roughest landscapes in the Ozark Highlands region of Missouri. Topographic roughness insulates forests from many types of human and natural terrestrial disturbances such as wildland fire. Here, we define and calculate topographic roughness and discuss the relevance of topographic roughness to the natural heritage and silvicultural practices of Pioneer Forest.

A perspective on quercus life history characteristics and forest disturbance
(Richard P. Guyette, Rose-Marie Muzika, John Kabrick, and Michael C. Stambaugh):

Plant strategy theory suggests that life history characteristics reflect growth and reproductive adaptations to environmental disturbance. Species characteristics and abundance should correspond to predictions based on competitive ability and maximizing fitness in a given disturbance environment. A significant canonical correlation between oak growth attributes (height growth, xylem permeability, shade tolerance) and reproductive attributes (longevity, acorn weight, and the age to reproduction) based on published values indicates that the distribution of oak attributes among species is consistent with r and K selection theory. Growth and reproductive attributes were used to calculate an index reflecting the relative values of the r and K strategies of oak species. This index was used to examine changes in the dominance of oak species at nine sites in the Ozarks. Changes in oak species dominance and differences in their landscape distributions were consistent with predictions based on their r & K index values and estimates of forest disturbance.

Riparian fire (Guyette and Stambaugh)
The fire regimes of floodplains and riparian forests have not been previously studied because of the lack of historical and biological data. We document and empirically model the fire regime of the riparian corridor of the Current and Jacks Fork Rivers, Missouri, U.S.A Fire histories were constructed at three sites adjacent to the rivers using 409 fire scars dated on shortleaf pine (*Pinus echinata*) remnants. Temporal changes in the length of mean fire intervals in the riparian corridor were consistent with changes in human population and culture found in previous studies. The mean fire intervals by periods for the riparian corridor sites were 13 years (1700-1780), 3.4 years (1781-1820), 2.2 years (1821-1890), 3.7 years (1891-1940), and >61 years (1941-2002). The mean fire intervals during pre-European periods in floodplains averaged 40 years (1620-1700), 20 years (1701-1780), and 10 years (1781-1820) but varied greatly by elevation and river reach. Surface fuel weight in floodplains was correlated with elevation above the river ($r=0.74$, $p< 0.01$) and tree basal area (0.60, $p < 0.01$). Surface fuels in floodplains (weight: 620 g m^{-2}) weighed less than in uplands (1036 g m^{-2}). Fuel weights on the higher terraces were similar to uplands and burned as frequently as adjacent upland sites. The lowest elevations in the floodplains had surface fuel weights that were light (481 g m^{-2}) and variable (32 to 928 g m^{-2}).

Fire scar data indicated that the frequency of burning was greater in the lower reaches of the river that are generally characterized by broader floodplains, greater human population density, and a less topographically rough landscape. The frequency of burning potentially increased with elevation in the floodplain because the amount and continuity of surface fuels would favor the propagation of surface fires. Riparian mean fire intervals , mean fire intervals in floodplain forests, based on fire scars and fuels, were longer (50%) than that in adjacent uplands, especially in the upstream reaches (e.g., > river mile 75). Fire maps with 30 m pixel resolution were generated from three equations.

Fuel loading in giant cane (*Arundinaria gigantea*) patches was over twice as much as that in riparian forests. Cane patch size was related to river reach and fire history. Relative to other riparian species, the regeneration and recruitment of bur oaks (*Quercus macrocarpa*) was very low. Along the Current River present day bur oak abundance was associated with longer historic fire intervals. This association is probably an artifact of agricultural activity. Temporally, a pulse of bur oak recruitment occurred between 1860 and 1870 and is associated with the disruption of the agriculture during and after the Civil War.

The effects of humans and topography on wildland fire, forests, and species abundance (Richard P. Guyette and Daniel C. Dey):
Ignitions, fuels, topography, and climate interact through time to create temporal and spatial differences in the frequency of fire, which, in turn, affects ecosystem structure and function. In many ecosystems non-human ignitions are overwhelmed by anthropogenic ignitions. Human population density, culture, and topographic factors are quantitatively related to fire regimes and the long-term pattern in fire frequency and species composition. These factors can be quantitatively related and used to reconstruct and predict the frequency of fire in ecosystems and to identify changing factors involved in anthropogenic fire regimes. Quantitative fire histories from oak-pine sites in Arkansas, Indiana, Missouri, and Ontario are used to examine patterns of interaction in fuels, ignitions, and topography over a period of 300 years. Fire regimes and fire frequencies are associated with the abundance of many species of reptiles, birds, fungi, and plants. Human population density and topographic roughness are master variables in understanding temporal and spatial differences in fire regimes and their effects on ecosystems.

Scientific Outputs:

Publications

Guyette, R.P. Stambaugh, M.C. (in press). In the heart of roughness: Pioneer Forest. Proceeding of the Pioneer Forest Conference, St. Louis, Missouri. USDA Forest Service GTR.

Stambaugh, M.C., R.P. Guyette. 2004. The long-term growth and climate response of shortleaf pine at the Missouri Ozark Forest Ecosystem Project. In:(Yaussy et al. eds.) The Proceeding of the 14th Central Hardwoods Conference, Delaware, Ohio. USDA Forest Service GTR NE-316 . pp 448-458.

Stambaugh, M.C., R.M. Muzika, and R.P. Guyette. 2002. Disturbance characteristics and overstory composition of an old-growth shortleaf pine (Pinus echinata Mill.) forest in the Ozark Highlands, Missouri, USA. Natural Areas Journal 22:108-119.

Guyette, R.P. and J. Kabrick. 2003. The legacy of forest disturbance, succession, and species at the MOFEP sites. In:(S. Shifley, eds.) The Proceeding of the Second Missouri Ozark Forest Ecosystem Project Symposium. USDA Forest Service GTR NC-227.

Guyette, R.P. R.M. Muzika, C.D. Dey. 2002. Dynamics of an anthropogenic fire regime. Ecosystems. 5(5):472-486.

Guyette, R.P. and J. Kabrick. 2002. The legacy of forest disturbance, succession, and species at the MOFEP sites. In:(S. Shifley, eds.) The Proceeding of the Missouri Ozark Forest Ecosystem Project Symposium. USDA Forest Service GTR.

Guyette, R.P. and D. Larsen. 2000. A history of anthropogenic and natural disturbances in the area of the Missouri Ozark Forest Ecosystem Project. In: (S. Shifley and Brookshire eds.) Missouri Ozark Forest Ecosystem Project: Site history, soils, landforms, woody vegetation, down wood, and inventory methods for the landscape experiment. Gen. Tech. Rep. NC-208. North Central Research Station, USDA Forest Service, St. Paul Minnesota. 314 p.

Guyette, R.P. and B.E. Cutter. 1997. Fire history, population, and calcium cycling in the Current River Watershed. In:(Pallardy et al. eds.) Proceedings 11th Central Hardwood Forest Conference. USDA Forest Service GTR NC-188. 401 p.

Guyette, R.P. and D.C. Dey. 1997. Historic shortleaf pine (*Pinus echinata*) abundance and fire frequency in a mixed oak - pine forest (MOFEP site 8). In:(B. Brookshire and S. Shifley, eds.) The Proceeding of the Missouri Ozark Forest Ecosystem Project Symposium: An experimental approach to landscape research. USDA Forest Service GTR NC-193. 378 p.

Guyette, R.P. and C. Rabeni. 1995. Climate response among the rings of fish and trees. Oecologia 104:272-279.

Guyette, R.P. R.M. Muzika, J. Kabrick. M. Stambaugh. 2004. A perspective on *Quercus* life history characteristics and forest disturbance. In: (Spetich, M.A. ed.) Upland Oak Ecology Symposium: history current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Depart. of Agriculture, Forest Service Southern Res. Stat. 311 p.

Guyette, R.P. and D.C. Dey. 2004. The effects of humans and topography on wildland fire, forests, and species abundance. In: (Spetich, M.A. ed.) Upland Oak Ecology Symposium: history current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Depart. of Agriculture, Forest Service Southern Res. Stat. 311 p.

Dey D.C. R.P. Guyette, M.C. Stambaugh. 2004. Fire history of a forest, savanna, and fen mosaic at White Ranch State Forest. In: (Spetich, M.A. ed.) Upland Oak Ecology Symposium: history current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Depart. of Agriculture, Forest Service Southern Res. Stat. 311 p.

Guyette, R.P. and D.C. Dey, 2000. Human, topography, and wildland fire: the ingredients for long-term patterns in ecosystems. In: People, fire, and the Central Hardwood Landscape, D. Yaussey ed. March 12, 2000. Eastern Kentucky University, Richmond KY.

Dey, D.C. and R.P. Guyette. 2000. Sustaining oak ecosystems in the Central Hardwood Region: lessons from the past -- continuing the history of disturbance. Conference Transactions. 65th North American Wildlife and Natural Resources Conference, March 24-28, 2000, Rosemont. IL.

Guyette, R.P. and D.C. Dey. 1997. A fire history of Huckleberry Hollow. Forest Research Paper, No. 1.Missouri Department of Conservation.

Guyette, R.P. and D.C. Dey. 1997. Fire history at Panther Cave Hollow. Report for the Missouri Department of Conservation.

Guyette, R.P. and D. Larsen. 1997. Anthropogenic and natural disturbances at the MOFEP Compartments In: The establishment report. (in preparation).

Dey, C.D. Guyette, R.P., Stambaugh, M.C. 2003. Ancient woods uncovered. Missouri Conservationist. 64 (1): 4-7.

Guyette, R.P., C.D.Dey, and M. Dey. 1999. An Ozark fire history. Missouri Conservationist. 60(3): 4-7.

Guyette, R.P. 1978. Window Into Time. The Missouri Conservationist. November 1978.

Guyette, R.P. 1981. "Flooding and tree growth in green tree reservoirs." Report for the Mo. Dept. Conservation.

Invited Presentations

Guyette, R.P. Stambaugh, M., and Dey, D.C. 2004. Human, topographic, and climatic influences on fire regimes in mid and eastern North America. Ecological Society of American. Symposium presentation: Cultural and Environmental Controls on Past Fire Regimes in Inhabited Woodlands. Portland, Oregon.

Muzika, R. M. and R.P. Guyette. 2003. "Tree and stand-level predictors of red oak borer (Enaphalodes rufulus) activity". Special Symposium on Tree-Insect interactions Symposium, Entomological Society of American Annual Meeting, Cincinnati, Ohio. October 2000.

Guyette, R.P. Stambaugh, M., and Dey, D.C. 2003. The effects of climate, humans and topography on Missouri forests. Invited speaker. Upland forest workshop. Van Buren, Missouri.

Guyette, R.P. Stambaugh, M., and Dey, D.C. 2004. Human, topographic, and climatic influences on fire regimes in mid and eastern North America. Ecological Society of American. Abstract. Cultural and Environmental Controls on Past Fire Regimes in Inhabited Woodlands. Portland, Oregon.

Guyette, R.P., Dey. D.C.2002. The effects of humans and topography on wildland fire, forests, and species abundance. Abstract. Oak Ecology Symposium, Fayetteville, Arkansas.

Muzika, R. M. and R.P. Guyette. 2002 "Red Oak Borer in the Ozarks – Historical Perspectives" North Central Forest Pest Workshop, Postosi, Missouri. October 2002.

Guyette, R.P., Dey. D.C.2002. The effects of humans and topography on wildland fire, forests, and species abundance. Invited Presentation. Oak Ecology Symposium, Fayetteville, Arkansas.

Dey, D.C. and R.P. Guyette. 2000. Sustaining oak ecosystems: continuing the history of disturbance. 65th North American Wildlife and Natural Resources Conference. Rosemont, IL

Guyette, R.P. 2000. The legacy of forest disturbance, succession, and species at the MOFEP sites. Invited presentation. Shawnee Hills Forest Symposium, Carbondale Ill.
Guyette, R.P. 2001. Fire, humans, topographic roughness and species abundances. Invited presentation. Society of Range Management. Fire Symposium. Kansas City, Missouri.

Guyette, R.P. and D.C. Dey, 2000. Human, topography, and wildland fire: the ingredients for long-term patterns in ecosystems. In: People, fire, and the Central Hardwood Landscape, D. Yaussey ed. March 12, 2000. Eastern Kentucky University, Richmond KY.

Stambaugh, M. and Guyette, R.P. 1999. Fire history in Missouri Savannas. Invited presentation. Missouri Savanna Workshop. Bolivar, Missouri.

Guyette, R.P. 1998. Long-term changes in environmental and tree-ring chemistry. Invited speaker. Published abstract and presentation. American Chemical Society, Boston, Ma.

Guyette, R.P. 1998. Fire history in the Current River watershed. Invited lecture. Illinois State Museum. Springfield, Ill.

Guyette, R.P. 1996. Tree-ring dating of coarse woody debris in lake littoral zones," Invited lecture for Field Limnology, Harkness Laboratory of Fisheries Research, University of Toronto, Ontario.

Guyette, R.P. 1995. Ancient eastern redcedar, ecology and esthetics of old growth forests. Natural Areas Conference. Invited presentation. Fayetteville, Arkansas.

Guyette, R.P., D. Dey and B. Cutter. 1995. Fire history of oak savannas in the Ozarks. Oak Savanna Conference. Invited presentation. Springfield, Missouri.

Guyette, R.P. 1995. The environmental chemistry of tree-rings," Invited seminar. Canadian National Geophysical Survey and the University of Laval, Quebec City, Quebec.

Guyette, R.P. 1995. Old trees and tree-rings in Missouri," Missouri Native Plant Society, Columbia.

Guyette, R.P. and B.E. Cutter. 1993. Long-term estimates of water use efficiency from calcium in tree rings. Invited presentation. EPA sponsored workshop on forest health on environmental monitoring. July 1993. Penn. State, State College, Penn. CRC press.

Guyette, R.P. 1991. Old trees and tree-rings in Missouri," Missouri Native Plant Society, St. Louis, Missouri.

Guyette, R.P. 1991. Tree-rings studies in Missouri. University of Missouri at St. Louis. Horticulture Club.

Guyette, R.P. 1991. Old and historic trees in Missouri, Cooper County Historical Society, Lone Elm, Missouri.

Guyette, R.P. 1988. Tree-ring chemistry. Invited lecturer, Oak Ridge National Laboratory, Oak Ridge Tennessee.

Guyette, R.P. 1986. Flooding and the drought of 1784 in St. Genevieve, Mo. St. Genevieve Historical Society, St. Genevieve Missouri.

Guyette, R.P. 1983. Ozark wildfire history from trees. U. S. Forest Service workshop on Managing fire effects, Springfield, Mo.

Offered presentations

Guyette, R.P.; Stambaugh, M.C.; Dey, D.C. 2004. Riparian and upland fire frequency models and maps of the Current River. Missouri Natural Resources Conference, 28-30 January 2004, Osage Beach, MO.

Stambaugh, M.C.; Guyette, R.P.; Dey, D.C. 2004. Riparian and upland mean fire interval models and maps of the Current River watershed, Missouri, USA. 1-6 August 2004. Ecological Society Annual Meeting. Portland, OR (poster).

Dey, D.C.; Guyette, R.P.; Stambaugh, M.C. 2003. Fire history of a forest, savanna and fen mosaic at White Ranch State Forest. 29-31 January 2003. Missouri Natural Resource Conference: facing resource issues of the Mid-West. Dey gave this presentation. Osage Beach, MO. (poster, publication 61)

Guyette, R.P. , Muzika, R.M., Kabrick, J. Stambaugh, M. A perspective on Quercus life history characteristics and forest disturbance. Poster. Oak Ecology Symposium, Fayetteville, Arkansas. Muzika, R. M. and R.P. Guyette. 2002. Long term evidence of red oak borer damage in the Missouri Ozarks. Southern Forest Insect Work Conference, Roanoke, Virginia.

Muzika R.M. and R.P. Guyette. 2002. Evidence of site and climate effects on historical occurrence of Enaphalodes rufulus (Coleoptera: Cerambycidae). IUFRO Joint Meeting: Ecology, Survey and Management of Forest Insects, Krakow, Poland.

Muzika R.M. and R.P. Guyette. 2002. A dendrochronological analysis of red oak borer populations. Upland Oak Symposium, Fayetteville, Arkansas.

Muzika R.M., Guyette, R.P., and Voelker, S.L. 2003. "Insights into the population dynamics of red oak borer (Enaphalodes rufulus). Missouri Natural Resources Conference, Lake of the Ozarks, Missouri (poster).

Muzika R.M., Guyette, R.P., and Voelker, S.L. 2003. Red oak borer and oak decline in the Ozark Highlands of Missouri. Annual Forest Service Forest Health Monitoring Meeting, Monterey, California (poster).

Stambaugh, M.C.; Dey, D.C.; Guyette, R.P. 2002. From historic fire regimes to prescribed burning practices. Stambaugh presented the talk at Streams – dividing and uniting the landscape. Missouri Natural Resources Conference. 30 Jan. – 1 Feb. 2002. Lake of the Ozarks, MO. (abstract)

Guyette, R.P.; Dey, D.C. 2002. The effects of humans and topography on wildland fire, forests and species abundance. Upland oak ecology: history, current conditions, and sustainability, a symposium. Fayetteville, AR. (publication 58).

Dey D.C. R.P. Guyette, M.C. Stambaugh. 2002. Fire history of White Ranch State Forest. Poster. Oak Ecology Symposium, Fayetteville, Arkansas.

Stambaugh, M, Dey, D.C., Guyette, R.P. From historic fire regimes to prescribed burning practices. Presentation. Missouri Natural Resources Conference. Lake Ozark, Missouri.

Guyette, R.P. 1999. Ecological succession in an anthropogenic fire regime. Published abstract and presentation. Missouri Natural Resources Conference, Lake Ozark, Feburary 4.

Guyette, R.P. 1998. Ecological succession of an anthropogenic fire regime. Published abstract and presentation. International Symposium on Society and Resource Management. Columbia, Mo. May 27.

Guyette, R.P. and D. Dey. 1998. Old growth characteristics of a mixed shortleaf pine-oak forest. Presentation and abstract. Missouri Natural Resources Conference. Lake of the Ozarks. February 11, 1998.

Guyette, R.; Dey, D.C. 1997. Historic shortleaf pine (Pinus echinata Mill.) abundance and fire frequency in a mixed oak-pine forest (MOFEP, compartment 8). Missouri Ozark Ecosystem Project Symposium. St. Louis, MO.

Guyette, R.; Dey D. C. 1998. Age and growth of shortleaf pine in an old growth pine-oak forest. Dey made the presentation at the Missouri Natural Resources Conference. Osage Beach, MO.

Guyette, R.; Cutter, B.; Dey, D. 1995. Fire frequency in oak savannas and woodlands. Midwest oak savanna and woodland ecosystems conference. Springfield, MO. (abstract published).

Guyette, R.P. 1995. Fire history in the Current River watershed. Paper presentation, Missouri Forestry, Fisheries, and Wildlife Conference. Lake of the Ozarks.

Guyette, R.P. and Rabeni, C. 1994. Correlation among growth rings of fish and trees. Paper presentation, Missouri Forestry, Fisheries, and Wildlife Conference. Lake of the Ozarks. Proceedings of Cedar Glade Symposium, Missouri Academy of Science. Branson, Missouri.

Data contributions:

Guyette RP. 1996. Tree-ring data, Ontario and Missouri. International Tree-Ring Data Bank. IGBP PAGES/World Data Center-A for Paleoclimatology Data Contribution Series # 92-014. NOAA/NGDC Paleoclimatology Program, Boulder CO. USA.

Guyette, R. 1992. Tree-ring data, Rymers Ranch, Missouri. International Tree-Ring Data Bank. IGBP PAGES/World Data Center-A for Paleoclimatology Data Contribution Series # 96-004. NOAA/NGDC Paleoclimatology Program, Boulder CO. USA.

Guyette,R.P., Stambaugh,M.C. 2003. Missouri Ozark Forest Ecosystem Project (MOFEP) Site 5. International Multiproxy Paleofire Database/ World Data Center-A for Paleoclimatology Data Contribution NOAA/NGDC Paleoclimatology Program, Boulder CO. USA.

Guyette,R.P., Stambaugh,M.C. 2003. Missouri Ozark Forest Ecosystem Project (MOFEP) Site 6. International Multiproxy Paleofire Database/ World Data Center-A for Paleoclimatology Data Contribution NOAA/NGDC Paleoclimatology Program, Boulder CO. USA.

Guyette, R.P. 1999. Fire history of MOFEP site 1. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P., Stambaugh, M.C. 2003. Fire history of MOFEP site 2. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P. 2002. Fire history of MOFEP site 3. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P. 2002. Fire history of MOFEP site 4. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P. and Stambaugh, M.C. 2002. Fire history of MOFEP site 5. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P. and Stambaugh, M.C. 2002. Fire history of MOFEP site 6. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P. 1997. Fire history of MOFEP site 7. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P. 1998. Fire history of MOFEP site 8. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Guyette, R.P. 2000. Fire history of MOFEP site 9. Missouri Ozark Forest Ecosystem Project Data Base, Missouri Department of Conservation, Jefferson City, Missouri.

Down wood and Snags

Project Title: Coarse woody debris and snags on upland oak sites in the Missouri Ozark Forest Ecosystem Project

Team Members: Randy Jensen and Stephen Shifley

Key Findings:

Down coarse woody debris (CWD) is an important but little-studied indicator of forest structure, fire risk, habitat quality, nutrient cycling, and carbon storage. Snags (standing dead trees) are closely linked to CWD because snags ultimately add to the pool of CWD.

CWD was inventoried in 1990-1991, 1994-1995 and 1999-2000 (post-treatment) using line transects within each overstory plot. Total combined length of transects was 27.75 miles of which about 1 mile of transect (total) passed through clearcuts. The 8,855 pieces of measured down wood covered about 1 mile of transect length or roughly 3.6 percent of the ground area (all MOFEP sites combined). Snags were inventoried during the course of each overstory measurement.

Down wood volume associated with individual silvicultural treatments sorted out in a logical order with total CWD for clearcut plots > group selection > single tree > intermediate thinning > no harvest.

Estimated mean volume, surface area, and percent of ground covered by down wood at each MOFEP site before and after harvest treatments. Standard deviations are shown in parentheses for the plot observations used to compute site means.

Site	Block	Treatment	Vol. of down wood, 1992[1]	Ground covered by down wood, 1992 (line transects)	Ground covered by down wood, 2000 (line transects)
			Ft³/ac	%	%
1	1	No harvest	194(127)	1.8 (1.0)	2.8
2	1	Uneven-aged	155(103)	1.5 (0.9)	3.4
3	1	Even-aged	302(266)	1.6 (1.2)	4.5
4	2	Uneven-aged	107 (67)	1.7 (1.4)	4.3
5	2	Even-aged	153(106)	1.7 (1.4)	3.9
6	2	No harvest	429(426)	2.9 (1.6)	3.1
7	3	Uneven-aged	225(312)	1.6 (1.1)	4.0
8	3	No harvest	250(166)	1.6 (1.2)	2.5
9	3	Even-aged	355(259)	1.2 (1.0)	2.9
Overall mean			241	1.7	3.5

[1] Metric equivalents: 0.25 ac = 0.1 ha; $m^3/ha = (ft^3/ac)/14.29$; $m^2/ha = (ft^2/ac)/4.356$.

Estimated volume and percent ground cover for down wood by treatment group (n = 3 sites per treatment). Includes trees > 11cm (4.5 inches) dbh.

Site	Block	Treatment	Vol. of down wood, '95[1]	Vol. of down wood, '00	Ground covered by down wood, '95	Ground covered by down wood, '00
			Ft^3/ac	*Ft^3/ac*	*%*	*%*
1	1	No harvest	283	527	1.8	2.8
2	1	Uneven-aged	235	671	1.5	3.9
3	1	Even-aged	279	636	1.6	3.8
Overall mean			266	611	1.7	3.5

[1] Metric equivalents: 0.25 ac = 0.1 ha; m^3/ha = (ft^3/ac)/14.29; m^2/ha = (ft^2/ac)/4.356.

Estimated coarse wood debris and percent of ground covered by plot treatment, 1999-2000. Plot values were grouped by the actual silvicultural treatment that occurred on each plot.

Treatment	Volume of down wood	Ground cover
	Ft^2/ac	*%*
Clearcut	2300	12.4
Single tree w/ Group	1100	6.3
Single tree	800	4.6
Intermediate thinning	700	5.8
No harvest	400	2.4

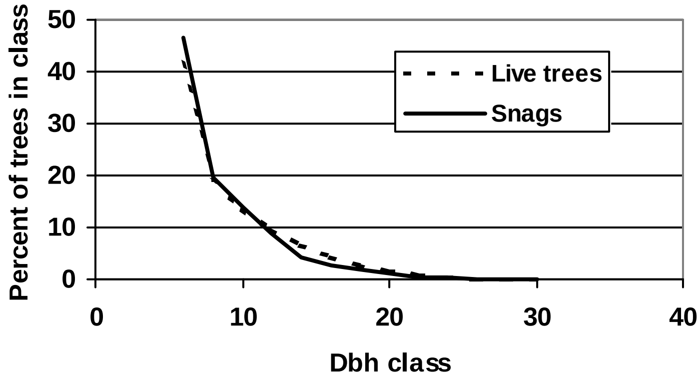
Estimated number and basal area of snags at each MOFEP site prior to treatment, trees ≥ 4.5 inches (11 cm) dbh, 1992. Standard deviations are shown in parentheses

Site	Block	Treatment	Density	Basal area	Quad. mean dbh	Ratio of snags to live trees
			No./ac	*Ft^2/ac*	*Inches*	*%*
1	1	No harvest	11 (7)	4.0 (3.1)	8.2	6
2	1	Uneven-aged	10 (6)	4.2 (2.9)	8.6	6
3	1	Even-aged	9 (6)	4.1 (3.3)	9.2	5
4	2	Uneven-aged	9 (7)	3.7 (3.1)	8.5	5
5	2	Even-aged	10 (6)	4.1 (3.0)	8.9	6
6	2	No harvest	13 (6)	7.3 (4.5)	10.3	8
7	3	Uneven-aged	17 (11)	7.3 (5.9)	9.0	12
8	3	No harvest	21 (12)	9.6 (6.1)	9.2	16
9	3	Even-aged	6 (5)	3.8 (3.7)	11.0	5
Overall mean			12	5.3	9.1	8

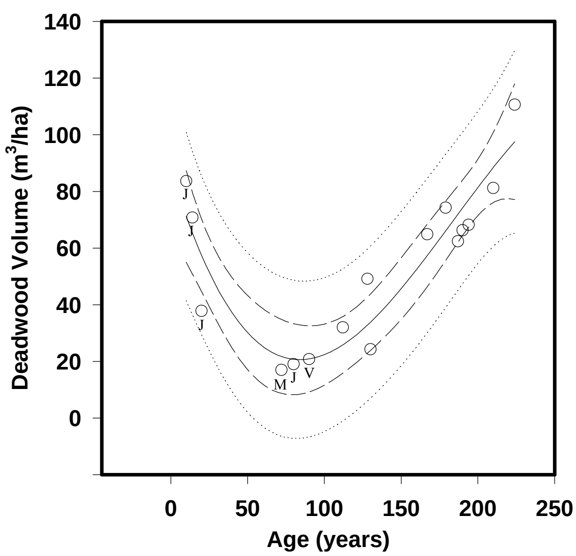
[1] Metric equivalents: number per ha = 2.47(number per ac); m^2/ha = (ft^2/ac)/4.356; 2.54 cm =1 in.

Prior to the 1997 harvest treatments there were no significant differences among treatment groups (n = 3 sites per treatment) in the mean value of CWD per acre or the percent of ground area covered by down wood. The volume and percent coverage of CWD approximately doubled before and after harvest treatments, even on the control plots. Prior to harvest treatments, snags comprised about 5 ft.2 basal area/ac with roughly 1 snag for every 10 to 12 live trees by dbh class.

Across all sites (pretreatment) the number of snags by diameter class had a reverse-J (negative exponential) shape. For a given dbh class, the mean number of snags per acre was approximately 10 percent of the number of live trees.



By combining MOFEP data with other sources of data representing other stand ages, we were able to model a CWD volume curve based on stand age. Regression of age vs. total down deadwood volume. Deadwood Vol. = 87.520 - 1.768 Age + 0.014 Age2 - 0.00002Age3 ; R2 = 0.862 and P-value <0.001. (Spetich et al. 1999)



2. What are the challenges you faced?

Sampling snags and/or CWD is difficult to accomplish with high precision because they are highly variable quantities across plots and over time. Line sampling is the most common method of CWD inventory, but the sampling characteristics of CWD inventories have not been explored in detail, particularly with respect to the changes in the standard error of the mean as sample size increases.

3. What new research issues need addressing in MOFEP?

Snags and CWD should continue to be periodically measured, particularly before and after harvest treatments. This will allow scientists to better quantify the magnitude and variability of the accumulation of snags and CWD in untreated stands. Also, little is known about rates of decomposition for snags and down wood. Untreated stands serve as a baseline useful for comparison of values for treated stands. Stands having any type of harvest generally increase in CWD due to the residual tops and limbs that are left behind. Periodic harvesting, particularly uneven-aged management with periodic thinning treatments, may eliminate trees that are prone to die and thus over time reduce the number of snags relative to untreated stands.

The volume of coarse woody debris of various sizes is indicative of fuel loading and ultimately of fire intensity if ignited. The MOFEP results could be used to support fire research and modeling efforts in the Ozarks. The Forest Service Forest Inventory and Analysis (FIA) program is now collecting CWD data on a small proportion of plots as part of their on-going state-wide inventories. The FIA CWD sampling is just beginning, and results from the periodic MOFEP CWD inventories can serve as a reference point from which to evaluate the early FIA results.

Inventories of snags and CWD present sampling challenges because they are highly variable at small spatial scales. Moreover, snags are relatively rare events. Recent work related to cavity tree estimation indicates that appropriate spatial scales can be determined for estimating current and predicted levels of cavity trees. A similar approach would likely be productive if applied to estimation and prediction of snag density or CWD at stand and landscape scales.

Scientific Outputs:

Publications

Herbeck, L.A. 1997. Analysis of Down Wood Volume and Percent Ground Cover for the Missouri Ozark Forest Ecosystem Project. pp 124-132 In Shifley, S. R., B. L. Brookshire (eds.). Missouri Ozark Forest Ecosystem Project: site history, soils, landforms, woody and herbaceous vegetation, down wood, and inventory methods for the landscape experiment. General Technical Report NC-208. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station

Shifley, S. R. 1995. Snags and down wood in old-growth and mature second-growth upland forests in Missouri. p49 In Abstracts, 22nd Annual Natural Areas Conference. October 25-28, Fayetteville, AR. 68p.

Shifley, S. R., B. L. Brookshire, D. R. Larsen, L. A. Herbeck. 1997. Snags and down wood in Missouri old-growth and mature second-growth forests. Northern Journal of Applied Forestry 14:165-172.

Shifley, S. R., B. L. Brookshire, D. R. Larsen, L. A. Herbeck, R. G. Jensen. 1997. Snags and down wood on upland oak sites in the Missouri Ozark Forest Ecosystem Project. pp 248-256 In B. L. Brookshire and S. R. Shifley(eds.). Proceedings of the Missouri Ozark Forest Ecosystem Project: An Experimental Approach to Landscape Research. June 3-5, 1997 St. Louis, MO. General Technical Report NC-193 St. Paul, MN. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

Shifley S. R. 1994. Missouri Forest Fish and Wildlife Conference, Osage Beach, MO. February 5, 1994. “Snags, course woody debris and cavities in Missouri old-growth forests.” [Abstract]
Spetich, M. A., S. R. Shifley and G. R. Parker. 1999. Regional distribution and dynamics of coarse woody debris in temperate deciduous old-growth forests. Forest Science. 45-302-313.

Tree Cavities

Project Title: Cavity abundance in the Southeast Missouri Ozark forest

Team Members: Randy Jensen, Mark Johanson , John Kabrick, and Eric Zenner

Project Goals:
1. Determine the effects of even-age, uneven-age, and no-harvest management on the density of cavity trees and snags.

2. Report trends in cavity tree data with respect to tree species, tree diameter, hole diameter, and hole height on the trees.

3. Verify the reliability of cavity estimates by dissecting into cavity trees after harvest and obtain internal cavity dimensions.

4. Make recommendations to managers on cavity tree and snag management with respect to cavity and snag using wildlife species.

Key Findings:
Pre-treatment cavity tree and snag densities were near or above optimum recommendations on MOFEP sites according to Missouri's forest land management guidelines (fig. 1 and 2). After timber harvests, cavity tree densities were above optimum recommendations on even-age and no-harvest sites, and only slightly below optimum recommendations on uneven-age sites (fig. 3). Snags were well above optimum recommendations on no-harvest and uneven-age sites and only slightly below optimum on even-age sites after timber harvests (fig.4).

Although 5% of the overstory trees were found to have cavities, there was a large difference in the frequency of cavities between species. Less than 1% of shortleaf pine had cavities but 20% of the blackgums had cavities. Oaks (2-10%) and hickories (7-11%) were found to be intermediate in cavity occurrence (fig. 5).

The frequency of cavities may be more related to tree size than tree species. Whereas the number of trees in 2 in. (5 cm) diameter classes had a negative exponential diameter curve, the proportion of live trees with a cavity had a positive exponential curve (q-value of 1.5) with increasing diameter classes (fig. 6). In all tree species, larger diameter trees had higher proportion of cavities than small diameters (fig. 7).

The largest proportion of holes leading to tree cavities (44%) was at less than 5 feet height on the tree (fig. 8). Cavities located high on trees were of the least abundance. We are unsure of how much value the basal cavities have for wildlife.

Another study was conducted by doing an intense search of cavities on 24 plots before and after clearcutting. About twice as many cavities were thought to have been found with the intense survey compared to a more general survey taken while collecting other overstory data. However, after dissecting the trees only 55% of the cavities that we thought existed met our minimum definition. But data collected on pre-cavities revealed that 18% of them were actually tree cavities. Overall, our post-harvest cavity density was 70% of the original estimate before clearcutting (fig. 9).

We were correct in calling all of the scarlet oaks cavity trees and 93% correct in calling white oaks cavity trees; compared to being correct only 61% of the time when estimating whether black oaks are cavity trees. These estimates would have been much lower had in not been for additional cavities that were estimated to be pre-cavities. Without these additions, the precision of white oak and scarlet oak cavity estimates would be 80% and 76%, respectively.

As expected, the larger the hole (fig.10) or the lower the hole height on the tree (fig.11), the more accurate we were in estimating whether holes actually led to tree cavities.

Scientific outputs:

Jensen, Randel G. 1994. The effects of forest management practices on the Southeast Missouri Ozark forest. Missouri Forest Ecosystem Project Annual Meeting, Jefferson City, MO. November 17, 1994. (presentation and abstract).

Jensen, Randel G. and David R. Larsen. 1995. Pre-treatment analysis of cavity abundance in the Southeast Missouri Ozark forest. 80th Ecological Society of America Meeting. Snowbird, UT (poster and published abstract).

Jensen, Randel G. 1995. Pre-treatment analysis of cavity and snag abundance in the Southeast Missouri Ozark forest. 57th Midwest Fish and Wildlife Conference. Detroit, MI (poster).

Jensen, Randy G. 1996. Pre-treatment analysis of cavity and snag abundance in the Southeast Missouri Ozarks. 9th Missouri Forest, Fish, and Wildlife Conference. Lake Ozark, MO. (presentation and abstract).

Jensen, Randy G., John M. Kabrick and Eric K. Zenner. 2000. Tree cavity estimation and verification in the Missouri Ozarks. 27th Annual Natural Areas Assoc. Conference and 2nd Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment Results of the Landscape Experiment, St. Louis, MO. October 17-18, 2000 (presentation and publication).

Jensen, Randy G. 2000. Pre-treatment woody vegetation inventory protocols. pp 134-147. In: Shifley, Stephen R.; Brookshire, Brian L.; eds. Missouri Ozark Forest Ecosystem Project Site History, Soils, Landforms, Woody and Herbaceous Vegetation, Down Wood, and Inventory Methods for the Landscape Experiment. Gen. Tech. Rep. NC-208. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. (refereed).

Kabrick, J. M., R. G. Jensen, D. R. Larsen, and S. R. Shifley. 2002. Woody vegetation following even-aged, uneven-aged, and no harvest treatments on the Missouri Forest Ecosystem Project (MOFEP). p. 84-101 In: S. R. Shifley and J. M. Kabrick (eds.) Proceedings of the second Missouri Ozark Forest Ecosystem Symposium: post treatment results of the landscape experiment. October 17-20, 2000; St. Louis, MO. General Technical Report NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 228p. (presentation and publication).

Shifley, S. R., B. L. Brookshire, D. R. Larsen, and L. A. Herbeck. 1997. Snags and down wood in Missouri old-growth and mature second-growth forests. Northern Journal of Applied Forestry 14 (4):165-172. (Refereed)

Shifley, S. R., B. L. Brookshire, D. R. Larsen, L. A. Herbeck, and R. G. Jensen. 1997. Snags and down wood on upland oak sites in the Missouri Ozark Forest Ecosystem Project. p. 248-256 In: Brookshire, B. L. and. S. R. Shifley (eds.). Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. General Technical Report NC-192. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 378p. (presentation and publication).

Shifley, S. R., F. R. Thompson III, and B. L. Brookshire. 1994. Snags, course woody debris and cavities in Missouri old-growth forests. Missouri Forest, Fish, and Wildlife Conference (Joint meeting of Missouri chapters of SAF, Fisheries Society and Wildlife Society), Lake Ozark, MO. February 5, 1994. (Abstract)

MOFEP cavity tree and snag data used:

Fan, Zhaofei; Larsen, David R.; Shifley, Stephen R.; Thompson, Frank R. 2003. Estimating cavity tree abundance by stand age and basal area, Missouri, USA. Forest Ecology and Management. 179(1-3): 231-242.

Fan, Zhaofei; Shifley, Stephen R.; Spetich, Martin A.; Thompson, Frank R., III; Larsen, David R. 2003. Distribution of cavity trees in midwestern old-growth and second-growth forests. Canadian Journal of Forest Research. 33(8): 1481-1494.

Fan, Zhaofei, Stephen R. Shifley, Martin A. Spetich, Frank R. Thompson III, and David R. Larsen. 2004 (In press). Abundance and size distribution of cavity trees in second-growth and old-growth Central Hardwood Forests. Northern Journal of Applied Forestry.

2004/05 Research Plans:

None in fiscal year 2005. We plan to collect cavity and snag data in the fall of 2005 through the spring of 2006 along with the general overstory data set.

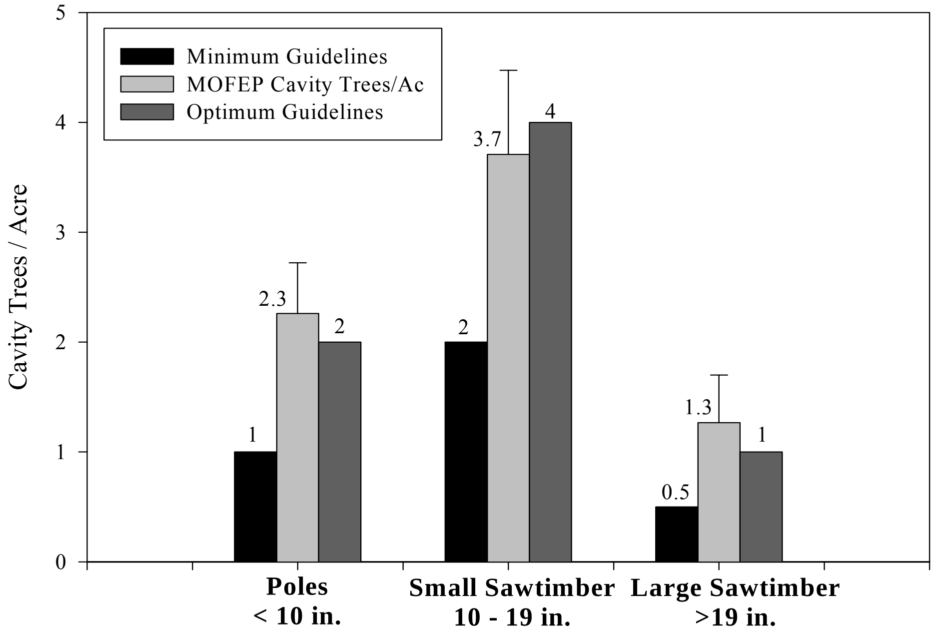


Figure 1. Pre-harvest cavity tree ($\geq$ 4.5 in (11 cm) dbh) densities for pole timber, small sawtimber, and large sawtimber on all MOFEP sites compared to the land management guidelines for Missouri's heavily forested areas. Error bars are 95% confidence intervals for site means. Numbers on bars indicate site means or minimum and optimum recommendations.

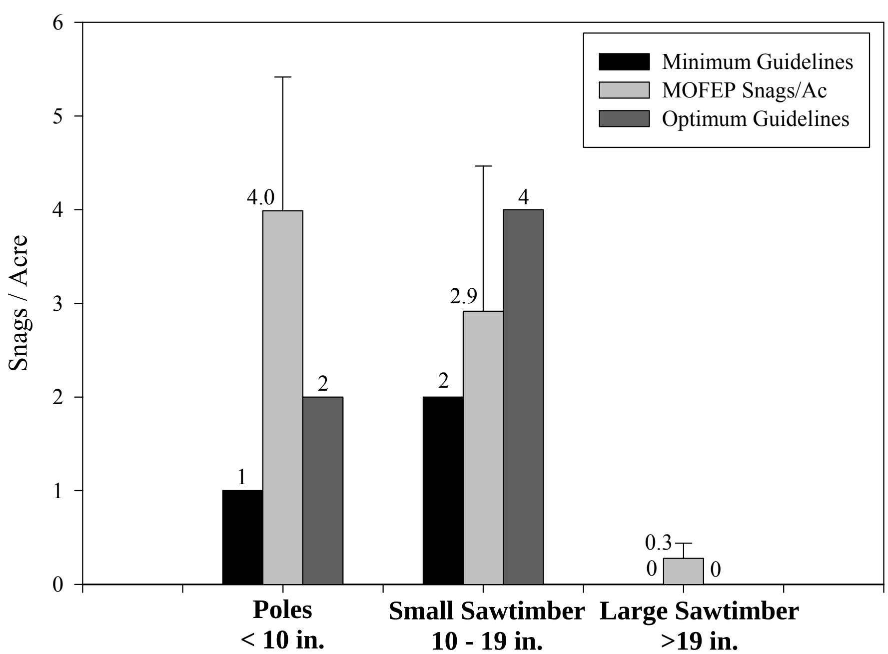


Figure 2. The density of snags ($\geq$ 6 in (15 cm) dbh) on pre-treatment MOFEP vegetation plots in 1994-95, and a comparison to the recommended snag guidelines for Missouri's heavily forested regions. Error bars are 95% confidence intervals for site means. Numbers on bars indicate site means or minimum and optimum recommendations.

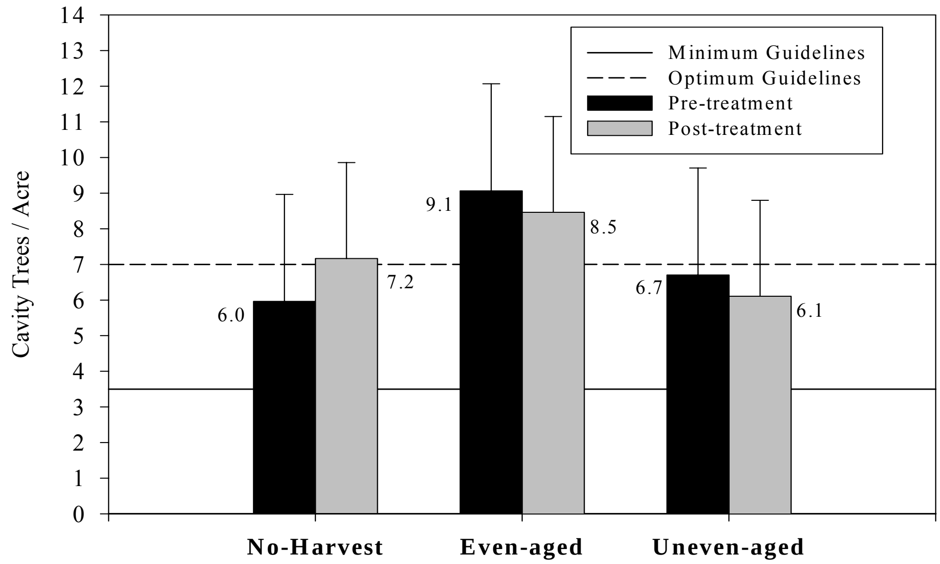


Figure 3. Pre-harvest and post- harvest cavity tree densities ($\geq$ 4.5 in (11 cm) dbh) by forest management on MOFEP sites compared to the land management guidelines (combined size classes) for Missouri's heavily forested areas. Error bars are 95% confidence intervals for site means. Numbers on bars indicate treatment means.

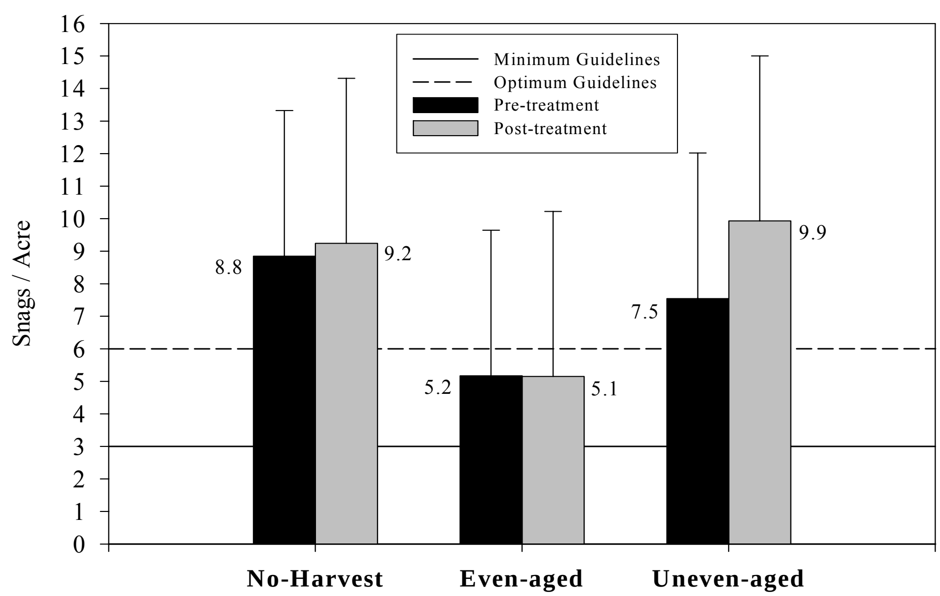


Figure 4. Pre-harvest and post- harvest snag densities ($\geq$ 6 in (15 cm) dbh) by forest management on MOFEP sites compared to the land management guidelines (combined size classes) for Missouri's heavily forested areas. Error bars are 95% confidence intervals for site means. Numbers on bars indicate site means.

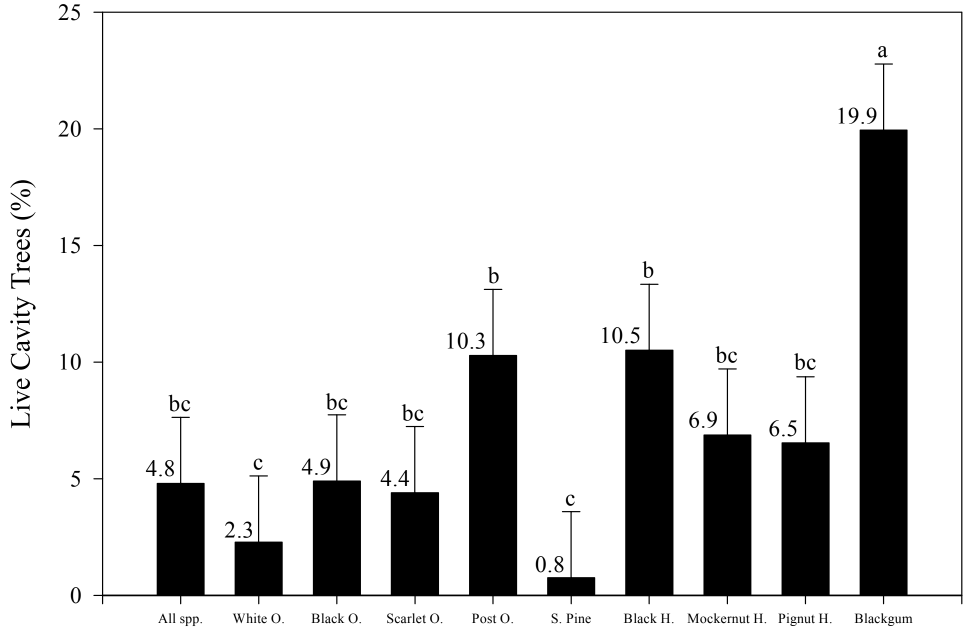


Figure 5. The relative abundance of cavity trees for all trees (≥ 4.5 in (11 cm) dbh) and the most abundant tree species on MOFEP sites prior to harvest. Error bars are 95% confidence intervals for site means. Different letters indicate significant differences in abundance of live cavity trees (%) among species based on a Tukey test. Same or shared letters indicate no significant difference at ∀ = 0.05 level.

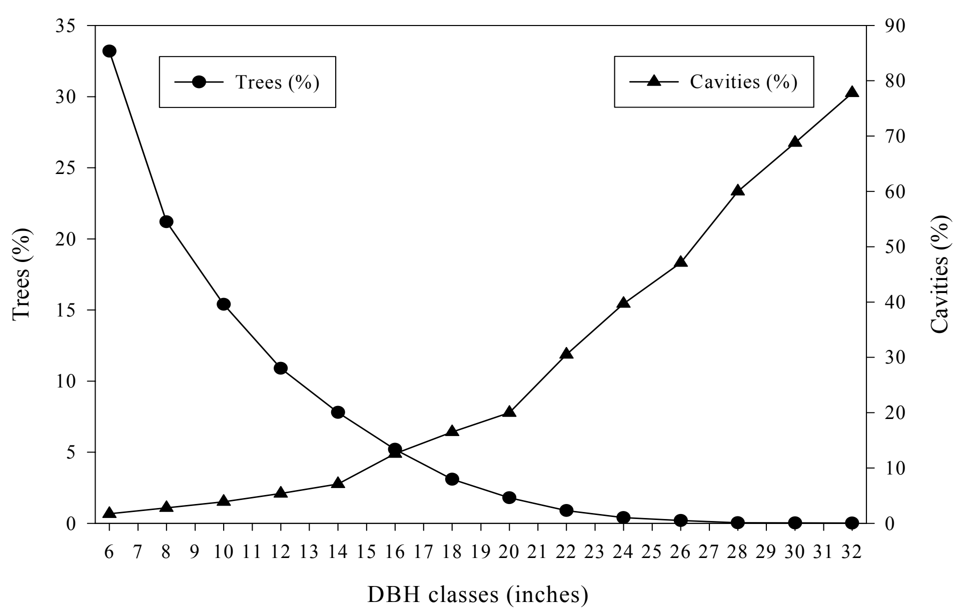


Figure 6. Pre-treatment diameter distribution of overstory trees (≥ 4.5 in (11 cm) dbh) on MOFEP sites and the corresponding percent of cavity trees by size class.

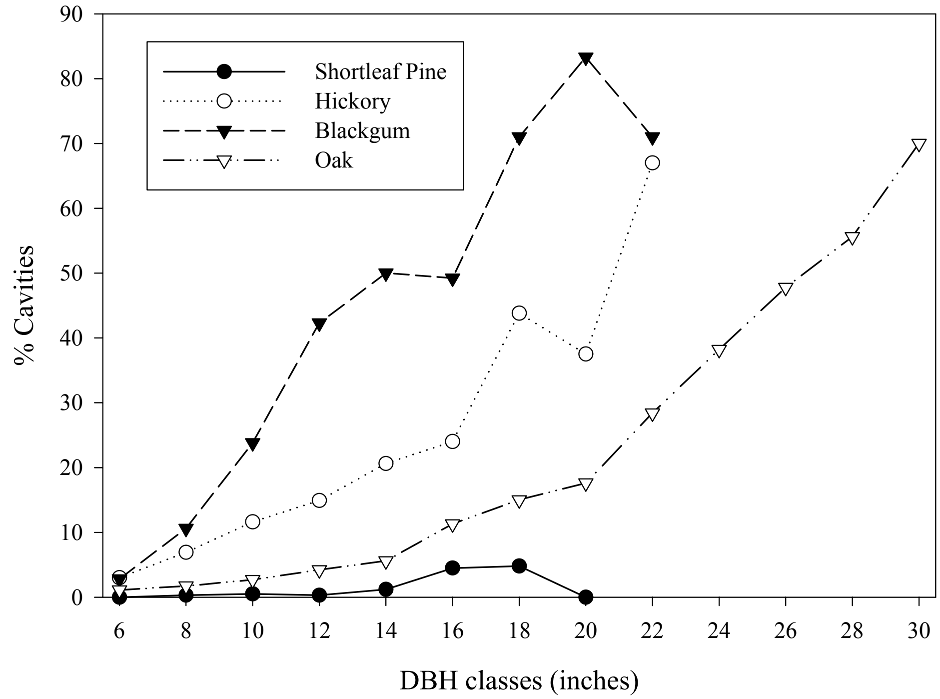


Figure 7. The pre-treatment diameter distribution for select species and species groups (≥ 5 in (13 cm) dbh) on MOFEP sites and the corresponding percent of cavity trees by 2 in. (5 cm) size classes. The last data point for each species or species group includes larger trees when their sample size would have been less than 10 otherwise.

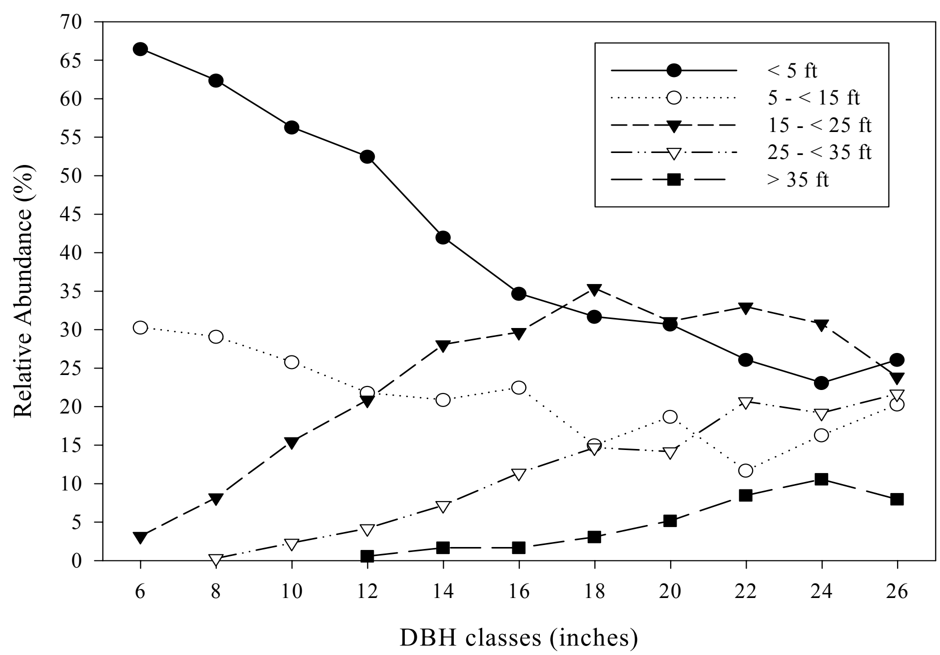


Figure 8. The relative abundance of cavity hole height locations on trees (≥ 5 in (13 cm) dbh) prior to MOFEP timber harvests by 2 in. (5 cm) size classes.

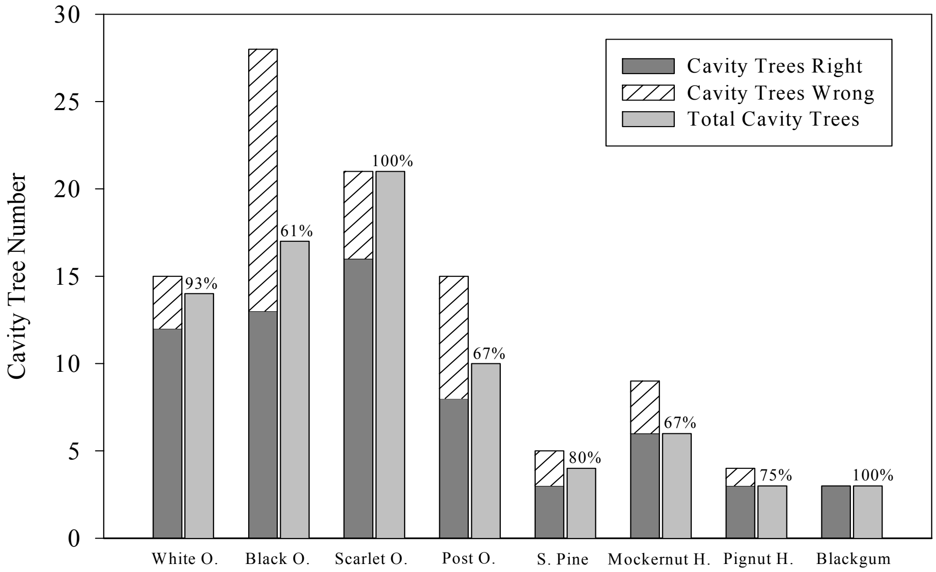


Figure 9. The number of cavity trees by species estimated by an intensive cavity search, including the number of confirmed cavity trees of the original estimate (dark gray), cavities that were not confirmed (hatched), and the total number of cavity trees including potential cavities that turned out to be cavities (light gray). The number above the light gray bar indicates this proportion of the original cavity estimate.

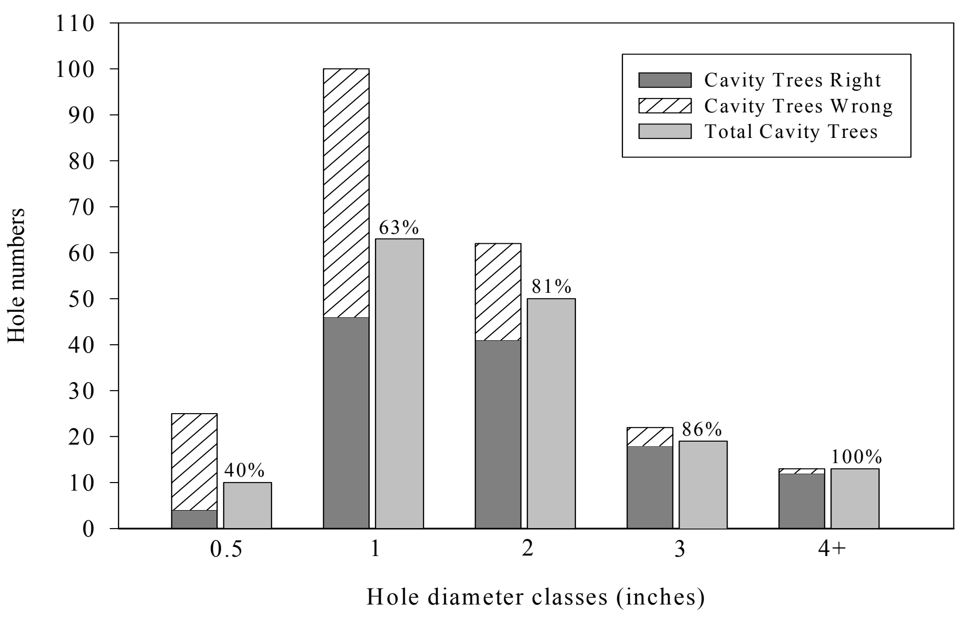


Figure 10. The proportion of holes that were successfully estimated to lead to a cavity with an intensive cavity search by hole diameter class, including the number of confirmed cavity trees of the original estimate (dark gray), cavities that were not confirmed (hatched), and the total number of cavity trees including potential cavities that turned out to be cavities (light gray). The number above the light gray bar indicates this proportion of the original cavity estimate.

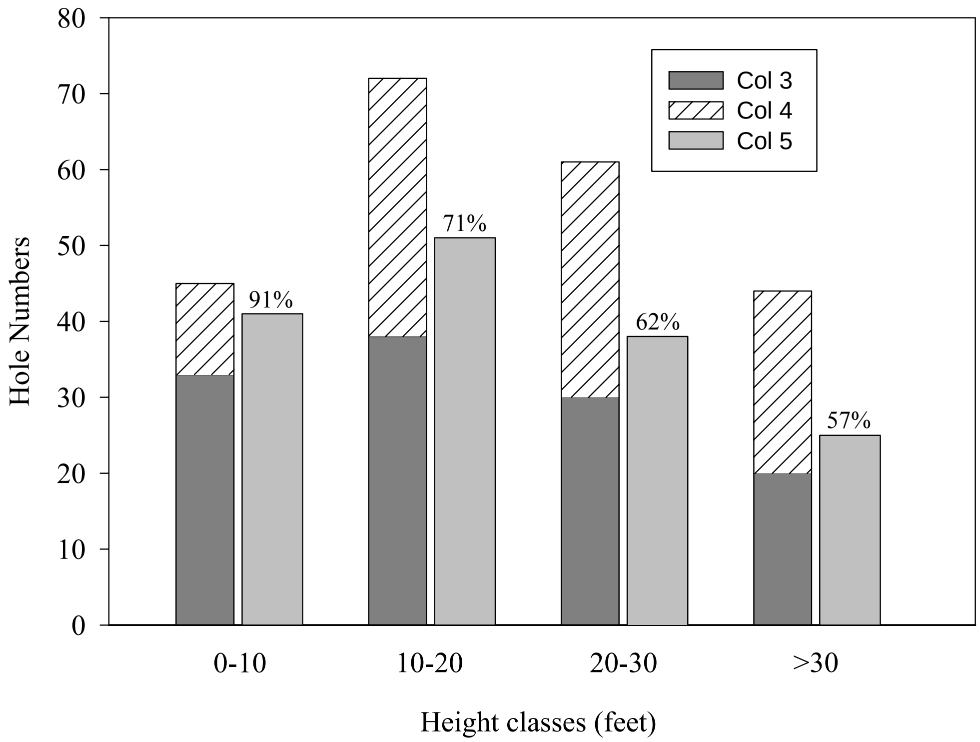


Figure 11. The proportion of holes correctly estimated to lead to a cavity with an intensive cavity search by hole height class, including the number of confirmed cavities of the original estimate (dark gray), cavities that were not confirmed (hatched), and the total number of cavity trees including potential cavities that turned out to be cavities (light gray). The number above the light gray bar indicates this proportion of the original cavity estimate.

Carbon Flux and Storage

Project Title: Carbon Flux and storage in mixed oak forests of Missouri Ozark Forest Ecosystem Project

Team Members: Jiquan Chen, Daryl Moorhead, Randy Jensen, John Kabrick

Project Objectives:
The primary objective of this study is to quantify differences in carbon flux and storage in mixed oak forests of the Southeastern Missouri Ozarks in response to management practices, landscape form, and climate change. The experimental compartments of MOFEP will be used to collect empirical data for predicting net carbon exchanges (NCE ~ net ecosystem productivity) at multiple temporal scales (monthly to century). These predictions will be extended to provide a spatial context of NCE and C storage using processed Landsat imagery, in conjunction with ecological land type phases (ELTP) and digital elevation model (DEM) databases.

The four major tasks of this project are: (1) to quantify carbon flux and storage in MOFEP compartments and dominant ELTPs using conventional biometric methods; (2) to parameterize production and decomposition models (i.e., PnET and GENDEC) with site-specific measurements from MOFEP compartments and dominant ELTPs, (3) to simulate changes in NCE and C storage over 100-year periods, and (4) to measure carbon flux in the field for testing model performance and increasing model precision. Since July 2002, we have primarily focused on field data collection, preliminary data analysis and collaboration with other ongoing projects for manuscript preparation.

Key Findings:
We have completed field data collection of soil respiration, photosynthesis of dominant tree species, litter decomposition and associated lab analysis (e.g., chemistry), litter-fall, root biomass, soil chemistry (lab processing), soil temperature, as well as established two new microclimatic stations. All data have been added to the MOFEP Database (http://mofep.conservation.state.mo.us/. Hemispherical photos of the MOFEP compartment were archived in 5 CDs and mailed to the MOFEP Coordinator (Dr. David Gwaze). Three peer-reviewed publications, two submitted manuscripts, and one M.S. Thesis have been completed, which utilize results of our work to date. Five presentations also have been made at scientific meetings (e.g., ESA Annual Meetings). Both the PnET and GENDEC models are being customized for the MOFEP study. The interactive version of PnET model already is available at http://research.eeescience.utoledo.edu/lees/research/jfsp/model/pnet/pnet_step1.asp, allowing any user to run the model via the Internet. Six Landsat TM images

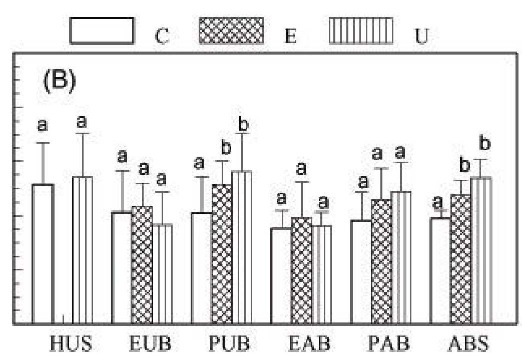


Fig. 1. Mean and standard deviation of soil respiration rate patch type and treatment type. Patch types at MOFEP were high ultic shoulder/shldr-ridge, bench (HUS), exposed ultic back-slope (EUB), protected ultic back-slope (PUB), exposed alfic back-slope (EAB), protected alfic back-slope (PAB), alfic bench or shoulder-ridge(ABS).

(2003, 1996, 1992, 1984, and 1976) have been purchased through collaborations with the JFSP project (Chen). Image processing is under way to predict changes in biomass across Ozark Landscapes 1970-2003.

Soil respiration is a major source of carbon efflux in forests, averaged 4.14 μmol m^{-2} s^{-2} at MOFEP, and was significantly different by site and management within site (Fig. 1, F=43.23, P=0.0012; F=10.21, P=0.0026, respectively). Clearcuts and single-tree removal had different effects on soil respiration rate. Respiration in clearcut soils was not significantly different from the controls, but was elevated by single tree-selection. Soil respiration also was significantly different among ELTP; mean respiration with single-tree harvest increased compared to control in protected ultic back-slope sites, protected alfic back-slope, and alfic bench or shoulder-ridge sites, and decreased exposed ultic back-slope and exposed alfic back-slope sites.

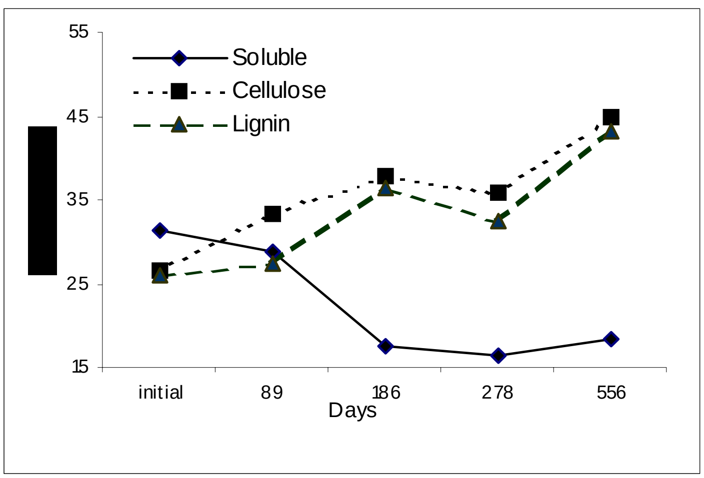


Fig. 2. Changing chemistry of decaying leaf litter during the study period.

Leaf litter decomposition was the major carbon input from living carbon pool to soil carbon pool. The litterbag study demonstrated that the 50.2% of mass was lost through decomposition after 580 days. Litterbag chemistry analysis shows that the three major carbon components, soluble, cellulose, and lignin, varied during the incubation. The soluble fraction decreased from 31% to 18% during this period (Fig 2), whereas cellulose and lignin fractions increased. Surprisingly, the ratio of cellulose and lignin

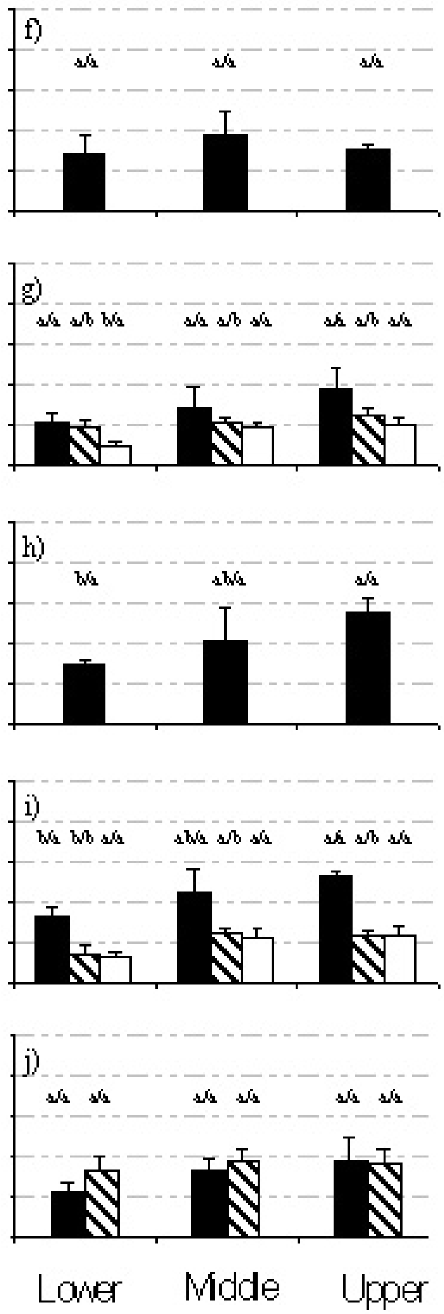


Fig. 3. Stomata conductance ($g_{s,max}$, μmol m^{-2} s^{-1}) of major species by canopy position and age structure. Black indicates mature stands, stripped indicates intermediate and white indicates young stands. (f) shortleaf pine, (g) scarlet oak, (h) black oak, (i) white oak, and (j) hickory.

varied little during this period, demonstrating a lower than expected relative rate of cellulose decay. Comparable results in an independent study being conducted in Manistee Forest (Michigan; Moorhead) were found for low-nutrient litter decay on low nutrient-sites. These results suggest low nutrient availability in some MOFEP units.

Photosynthesis is the major carbon sink in forest ecosystem, and was measured in major species on MOFEP sites (white oak, black oak, scarlet oak, hickory and short leaf pine) at three different age classes: young (<10 years), intermediate (15-25 years), and mature (>80 years); and at three canopy levels (upper, middle and lower, Fig. 3). The average photosynthetic rate among all species under control conditions (1500 μmol photons m^{-2} s^{-1} PAR and 360 μmol/mol ambient CO_2) was 7.97 and 8.23 μmol C m^{-2} s^{-2} for Aci curve and light response curves, respectively. The average maximum photosynthetic rate among all the species was 19.7 and 8.46 μmol C m^{-2} s^{-2} for the CO_2 and light response, respectively. Upper canopy positions typically showed greater photosynthetic capability than lower positions, for all species ($p<0.0001$ to 0.0125). Specific leaf weight was the best predictor of photosynthetic rate among measured factors (SPAD chlorophyll concentration, vapor pressure deficit, temperature, and fraction of PAR intercepted).

Future Plans:

Research plans include continuing field data collection, maintaining the two weather stations, updating data archives for MOFEP, and data analysis for publications. We have field data for two full growing seasons in 2003 and 2004, as well as an extensive litter decomposition study spanning more than 2 years. Another season of field-work would greatly enhance the value of this study by providing sufficient data to establish a level of inter-annual variation in ecosystem behavior (n=3 years). We have planned the following activities:

- Monthly soil respiration measurements at 62 selected plots.
- Monthly litter-fall collections from 104 litter traps.
- Monthly maintenance and data acquisition from 36 HOBO data loggers.
- Bi-weekly maintenance and data acquisition from the 2 microclimate stations.
- Hemispheric photos at 36 vegetation plots and along, five 100 meter transects
- Hemispheric photos at 104 hardmast traps.
- Organizing the database of overstory, litter-fall, CWD, soil total carbon, and ground litter for quantifying carbon pools.
- Conducting mass loss and chemistry analysis of litterbags from the last scheduled collection in summer 2005.
- Measuring foliar C and N content using a CHN Analyzer at the LEES lab.
- Parameterizing PnET and GENDEC models for modeling studies.
- Processing 5 Landsat TM images

Data analysis and manuscript development will be our primary focus for 2004/2005:

- Alterations of silvicultural treatments on carbon pools at MOFEP Forests (*Ecol. Appl.*).
- The effects of canopy removals on soil C efflux in mixed oak forests (*For. Ecol. Manage.*).
- Contributions of decomposition to ecosystem carbon flux and storage in mixed oak forests of the Missouri Ozarks (*Ecol. Modeling*).
- Changes in above ground biomass in Ozarks: 1975 – 2003 (*Rem. Sensing of Environ.*).

- Spatial variations of soil carbon fluxes affected by experimental treatments (*Plant & Soils*)
- Current and future carbon fluxes of Ozark Landscapes: a modeling approach (PnET).

Scientific Outputs:

Publications

Chen, J. (1994). Landscape Ecology and Ecosystem Management. Pages 69-70. In: CAS (Ed.) Sustainable Development, Beijing, China.

Chen, J. (1995). Principles of landscape ecology and its applications in ecosystem management. Pages 108-128. In: B. Li (Ed.), Lectures in Modern Ecology. Science Press, Beijing, China.

Chen, J., M. Xu, and K.D. Brosofske (1997). Microclimatic characteristics in southeastern Missouri's Ozarks. USDA Forest Service General Technical Report Nc-193: 120-133.

Song, B., J. Chen, P. Desanker, D.REED, J.F. Franklin, and G.A. Bradshaw (1997). Modeling canopy structure and heterogeneity across scales: from crown to canopy. Forest Ecology and Management 96: 217-229.

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Armillaria

Project Title: Missouri Ozark Forest Ecosystem Project armillaria-related forest structure and decline dynamics studies

Team Members: Johann N. Bruhn, Jeanne D. Mihail, James J. Wetteroff, Jr., Susan Taylor, Deana Baucom

Project Objectives:

1. At our selected set of permanent MOFEP vegetation-study plots, we continue to collect additional mapped *Armillaria* field isolates. These isolates will be used:
   a. to study the spatial and host distributions of *Armillaria* species (and their genets) re:
      1) land type association and landform position;
      2) oak decline (host species and condition);
      3) colonization strategies and niche partitioning interactions;
      4) silvicultural disturbance; and
      5) shifts in frequency of detection and/or behavior.
   b. in reciprocal placement common garden experiments to determine whether genets growing on different landform positions have been ecologically selected by their environments.
2. Beyond our normal sampling, we will emphasize stump colonization to evaluate sprout survival and growth with respect to presence/absence of *Armillaria* species.
3. We are developing molecular protocols for distinguishing *Armillaria* field isolates to species.
4. We have transferred our MOFEP *Armillaria* isolate collection to ultra-low temperature storage.
5. We will analyze and publish 5-year post-harvest wound closure data.
6. We will publish an overview of our current understanding of the role of *Armillaria* in oak decline.

Key Findings:

Preliminary data show that seven years after harvest the majority of oak stumps, whether sprouting or not, supported at least one active Armillaria infection at the root crown. Over 75% of evaluated stumps supporting at least three live sprouts also supported at least one such infection, as did nearly half of the stumps with at least five living sprouts. The majority of stumps in each diameter class, whether sprouting or not, supported at least one such Armillaria infection at the root crown. It will be important to identify the Armillaria spp. responsible for these infections in order to interpret their ecological role.

Sprout stem age is poorly related to root system age and Armillaria inoculum load. With the decay of the parent stump, the only evidence of a stem's origin may be the presence of decayed root channels. In rocky Ozark soils, Armillaria-decayed root channels are attractive avenues for root development, bringing live roots into contact with Armillaria inocula.

A new Armillaria cultural morphotype most closely resembling A. mellea, collected first in 2002, has a previously unpublished ITS PCR-RFLP banding pattern with AluI. We have also detected a new banding pattern among isolates which morphologically resemble A. gallica.

Scientific Outputs:

Refereed Publications

Mihail, J.D., and Bruhn, J.N. 2004. Bioluminescence of the fungi Armillaria gallica, A. mellea, and A. tabescens. New Phytologist (in revision).

Mihail, J.D., and Bruhn, J.N. 2004. Foraging behaviour of Armillaria rhizomorph systems. Mycological Research (in revision).

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Bruhn, J.N. 1993. The concept of the individual organism. Goddard Space Flight Center Engineering Colloquium. Greenbelt, MD. 1 March.

Outline of Research Plan for 2004-2005:

Collection of field isolates for spatio-temporal studies of Ozark forest decline

Collection and identification of Armillaria field isolates forms the basis for clarifying relationships between Armillaria spp. in MOFEP landscapes and their host species, geographic factors, and silvicultural disturbance. We continue to collect Armillaria isolates from: Armillaria mushrooms, mycelial fans from the root crown of recently killed trees, and stumps.

Evaluation of the role of Armillaria spp. in stump sprout development and survival

In 2002, we began finding oak stump sprouts killed by Armillaria root disease, and we also noted the asymmetrical distribution of stump sprouts. Preliminary data indicate that the circumferential distribution of stump sprouts is often related to the circumferential distribution of Armillaria-infected stump roots. We hypothesize that oak stump sprout production and long-term survival reflect Armillaria inoculum levels carried by stumps. If so, models of sprouting potential may overestimate sprout production and survival in stands undergoing decline in the presence of Armillaria. Therefore, this fiscal year we are revisiting the stumps on our long-term Armillaria study plots to evaluate sprout survival and growth and the presence/absence of active Armillaria infections at the root crown. These data will contribute to the re-parameterization of existing logistic regression models of stump sprout production and survival to reflect Armillaria root disease on sites vulnerable to decline.

Identification of Field Isolates to Species and Genet

The reason for identifying Armillaria isolates to species is to understand the field ecology of each Armillaria sp. with respect to oak decline. This work is being done with MOFEP isolates, but without MDC funding. Armillaria spp. differ in aggressiveness, in host tree species preference, and in foraging strategy. Where Armillaria species co-occur, their interactions may modify one another's behavior. Methods developed for identifying field isolates to species based on AluI RFLP patterns obtained from PCR amplification of portions of the IGS region of the ribosomal RNA gene have permitted us to identify many of our field isolates to the three species already recognized in the Ozarks. However, two previously unpublished Armillaria RFLP patterns have also come to light. One of these new RFLP patterns corresponds to a new culture morphology which has emerged since the first MOFEP harvest in 1996. We are currently working to determine whether these new RFLP patterns represent new species or new population segments within previously recognized species. In either case, this evidence that the MOFEP harvest may have selected for the emergence of a previously unknown form of Armillaria needs clarification.

We also need to identify the field isolates from several representative study plots to the genet level in order to understand the epidemiology of Armillaria spp. in the Ozarks. This will be attempted using somatic compatibility tests in pure culture confrontations. An important unresolved question is the nature of root disease pocket formation in Ozark oak decline. It has been presumed that A. mellea and A. tabescens root disease pockets form as individual genets spread from tree to tree across root contacts or by rhizomorphs, yet we are beginning to see evidence that individual mortality gaps may involve many A. mellea genets which have arisen from independently infections. Understanding the genet structure of the Ozark Armillaria species will tell us much about their respective infection strategies, the nature and effectiveness of interspecies competition related to oak decline, and the role of silvicultural disturbance in Ozark oak decline.

Data management and Archiving:

In consultation with Julie Fleming, MOFEP database manager, we are up-to-date in maintaining our data on the MOFEP website. By meeting time, we will have determined the appropriate disposition of unnecessary datasets.

Long-term Storage of Armillaria Isolates at Ultra Low Temperature

This storage method will save substantial technician time from culture maintenance that can be devoted to other research tasks, and will prevent genetic deterioration of our MOFEP isolates in culture. Preparation and placement into ultra-low temperature storage of our Armillaria isolates collection (over 1500 isolates from MOFEP) will be up-to-date by meeting time.

Analysis and publication of 5-year post-harvest wound closure measurements
In 2001, we re-measured all tree wounds mapped at the time of the first MOFEP harvest. We will analyze and publish our wound closure data.

Rhizomorph Foraging
This MOFEP-related study was conducted using MOFEP field isolates, but without MDC financial support. Understanding the foraging strategies of the Ozark Armillaria species will help us to better understand the competitive relationships among these species in stands where they co-occur. Our results have been submitted to Mycological Research for publication.

Bioluminescence
This MOFEP-related study is being conducted using MOFEP field isolates, but without MDC financial support. We hypothesize a relationship between Armillaria bioluminescence and as-yet-unidentified animals. We have characterized the bioluminescence patterns of Armillaria gallica, A. mellea and A. tabescens growing on dogwood root sections. Our results have been submitted to New Phytologist for publication.

Economics

Project Title: Missouri Ozark Forest Ecosystem Project long term growth and harvest simulation

Team Members: Tom Treiman, John Dwyer and David Larsen

Project Objectives:
Growth and harvest simulation is a project relying on secondary data from other MOFEP studies (e.g. Woody Vegetation). One of MOFEP's objectives is to test the long-term sustainability of the three management systems. Although MOFEP is primarily focused on biological sustainability, that sustainability, if it is to be applicable to non-experimental forest management, must include financial feasibility over the same long-term (one-hundred year or more) period. Among the essential requirements for timber yield sustainability are age and diameter class structure and growth rates that allow for approximately equal periodic yield of products of desired size and quality. Financial feasibility is achieved for any outcome with a positive financial return, but landowners and forest managers concerned primarily with financial returns will be interested in the treatment with the highest overall return. Even managers and landowners concerned with net benefits to society, themselves or their heirs, will still include financial benefits in their overall cost/benefit analysis.

Much of the software and many of the algorithms commonly used to simulate forest growth and harvesting activities have been optimized for short-term projections based primarily on larger-sized trees, and are focused on even-aged silvicultural systems. Using data on trees 1.5" DBH and larger from the Missouri Ozark Forest Ecosystem Project (MOFEP), we adapted the widely available Landscape Management System (LMS) and Forest Vegetation Simulator (FVS) software to make long-term simulations using even and uneven-aged silvicultural management systems. As noted, MOFEP is designed to test the long-term effects of even-aged, uneven-aged and no harvest treatments on a variety of ecosystem attributes. To simulate the economic outcomes of these three treatments, we use both standard algorithms and new LMS algorithms which simulate the effects of uneven-aged harvesting.

Our goal is to inform land managers or landowners of the results of management alternatives, as well as to reinforce the need to consider aesthetics, non-traditional forest products, and other non-market values in their decision matrix.

Key Findings:
Our results show that in the Missouri Ozarks even-aged and uneven-aged management silvicultural systems yield long-term (100 years) economic outcomes that are not statistically different. The NPVs of the EAM and UAM treatments were not statistically different from one another. The no harvest stands, unsurprisingly, had a projected net present value that was much lower, since no timber was actually harvested from these stands, all value coming from the residual stand. The table below shows the average values, volumes and NPV per acre by treatment.

Treatment	Harvest		Residual		Totals			N
	Volume	Value	Volume	Value	Volume	Value	NPV	
No harvest	0	$0	9,001	$1,312	9,001	$1,312	$10	185
					(3,193.5)	(462.4)	(3.5)	
EAM	7,125	$1,094	2,941	$455	10,066	$1,549	$320	207
					(3,673.5)	(576.2)	(335.6)	
UAM	2,928	$465	6,608	$973	9,536	$1,438	$263	198
					(3,379.9)	(504.3)	(297.1)	

Table 1 – Average volume (BF/acre), timber value (nominal dollars) per acre and timber NPV/acre by simulated treatment. Residual volumes and values represent the timber standing at the end of the 100 year simulation. N is the number of stands simulated for each, at a 5% discount rate.

In addition, we investigated the effects of different assumptions about future discount rates on the NPV of each simulated treatment.

Treatment	Discount Rate 1%	2%	3%	4%	5%	6%	7%	N
No harvest	$485[a]	$181[a]	$68[a]	$26[a]	$10[a]	$4[a]	$2[a]	185
	(170.97)	(63.83)	(24.06)	(9.16)	(3.52)	(1.36)	(0.53)	
EAM	$916[b]	$617[b]	$462[b]	$375[b]	$320[b]	$284[b]	$258[b]	207
	(415.60)	(366.15)	(346.52)	(338.39)	(335.57)	(335.24)	(336.02)	
UAM	$753[c]	$477[c]	$356[c]	$296[c]	$263[c]	$241[b]	$226[b]	198
	(351.09)	(324.47)	(312.51)	(303.44)	(297.06)	(293.09)	(290.90)	

Table 2 - Mean NPV/acre by simulated treatment and discount rate. N is the number of stands simulated for each treatment. Standard deviations are also presented in parentheses. Within each discount rate (column) means with the same letter are not significantly.

Depending on the discount rate used by the decision maker or manager, the silvicultural systems simulated for MOFEP either show no significant difference in NPV between UAM and EAM (for higher rates), or show EAM preferred to UAM (for lower rates), for the long-term one-hundred year period. Using yield as the criteria, neither UAM, EAM nor No Harvest (Control) is preferred. Under the scenarios that MDC has developed for MOFEP, neither UAM nor EAM can be said to be more financially attractive than the other in all cases. The overall value of the three treatments, however, includes other uses such as recreation or non-traditional forest products, non-consumptive uses, such as bequest to future generations, amenity values, such as scenic beauty, and the biological outcomes that are being monitored by other MOFEP studies. Another important difference between the two active silvicultural systems, is that the MOFEP even-aged treatment impacts many more acres (nearly one-half the stands) with heavy equipment traffic every 15 years (either harvesting or thinning), while the MOFEP uneven-aged treatment enter only one-third of the stands every 15 years with the same heavy equipment. These values and differences must be considered by managers of public land since the NPV decision criteria alone may not be decisive.

This conclusion is the result of simulations using LMS and FVS software that is currently state-of-the-art, although our finding cast some doubts on the software's ability to fully emulate UAM treatments. Further development of software and algorithm is needed to fully explore all the differences between the two. For example, we were not able to explore any differences in timber grade. In addition, we have assumed that loggers and timber buyers will pay similar stumpage prices for timber from both treatments, which may be incorrect in either direction. Currently, many Missouri loggers are unfamiliar with UAM and may regard it as more difficult and thus be less willing to pay. Conversely, if UAM management becomes viewed as more sustainable or more "eco-friendly" by the public than EAM ("clearcutting"), they may be willing to pay a premium.

Objectives, other than income, are important in making forest management decisions. The challenge will lie in developing metrics that allow for the comparison of the NPV of future cash flows and the non-market values mentioned above. Further research should be directed at conducting public surveys that will elicit public willingness-to-pay for the whole bundle of costs and benefits associated with each treatment into the future.

Scientific Outputs:

Publications

Treiman, Thomas; Dwyer, John; Larsen, David. *Forthcoming*. Long-Term Economic Simulation: Even-aged and Uneven-aged Examples from the Missouri Ozark Forest Ecosystem Project (MOFEP). N. J. of Appl. For.

Presentations

Treiman, Thomas; Dwyer, John; Larsen, David. The Missouri Ozark Forest Ecosystem Project: Evaluating Long-Term Even-Aged and Uneven-Aged Growth and Harvest Simulation. Accepted for presentation at ICESFM, 2003 (cancelled due to SARS in Toronto).

Outline of Research Plan for 2004/5:

No further activities planned until the next round of harvest.

Soft Mast

Project Title: Short term landscape-scale effects of forest management on abundance and production of berry-producing plants within the Missouri Ozark forest

Team Members: Debby K. Fantz, David A. Hamilton

Project Objectives:
The goal of our study was to experimentally evaluate the immediate impact of uneven-aged and even-aged forest management on plants that produce soft mast at the landscape level of the forest compartment.

This is a short summary of a paper that reports on the short-term compartment-level effects (one to five years after first-entry timber removal) of three timber harvest treatments (no-harvest, uneven-aged management and even-aged management) on mean percentage occurrence, mean number of berries per ha, and mean percentage vegetative coverage (0-1m) of plants producing soft mast on the MOFEP sites. We chose blueberries (*V. arboreum,* farkleberry; *V. vacillans,* lowbush blueberry; and *V. stamineum,* deerberry) and blackberries (*R. pensilvanicus*, high-bush blackberry; *R. occidentalis,* black raspberry; *R. enslenii,* dewberry; *R. flagellaris*, dewberry; and *R. trivialis,* southern dewberry) as our two focal groups for this report.

Key Findings:
We surveyed the permanent MOFEP forest vegetation cluster plots in the south central Missouri oak (*Quercus* sp.) - hickory (*Carya* sp.) - shortleaf pine (*Pinus echinata*) Ozark forests in 1994-1995 (pretreatment) and 1997-2001 (post-treatment) to determine the short-term (one to five years following timber harvest) effects of uneven-aged and even-aged timber management on abundance and production of plants that produce soft mast. We chose blueberries (*Vaccinium* sp.) and blackberries (*Rubus* sp.) as our two focal groups, and analyzed pretreatment to post-treatment differences in mean percentage occurrence per m^2 quadrat, mean percentage vegetative cover (0-1 m) per m^2 quadrat and mean numbers of berries per hectare. Generally, few soft mast plants were found, they provided little vegetative cover, and they rarely produced fruit in the plots prior to treatment.

However, statistically significant treatment effects were detected following harvest. The largest increase in berry production on cut sites was observed 3-4 years after timber harvest (6-26x more than before timber harvest). Most significant treatment effects were detected for *R. pensilvanicus.* Mean percentage occurrence and mean percentage cover (0-1m) increased 2-5 years after timber harvest, and the largest increase in berry production was observed 3-4 years after harvest (25-68x more than before timber harvest).

In general, uneven-aged and even-aged forest management had no short-term effect on *Vaccinium* sp. in the MOFEP plots. The largest increase in berry production for *V. vacillans* was observed on cut sites 3-4 years following timber harvest (4-11x more than before timber harvest). No treatment effect was detected for *R. enslenii, R. flagellaris, and R. trivialis* combined.

This study period represents the beginning of a long-term, harvest strategy and provides encouraging results for resource managers.

Mean number of berries per hectare for Rubus pensilvanicus for each MOFEP site by year. 1994-1995 represent pretreatment means, and 1997-2001 post-treatment means.

Site	1994	1995	1997	1998	1999	2000	2001
1	0.0	248.3	274.0	0.0	85.6	179.8	299.7
2	0.0	162.7	171.2	8.6	1387.0	3518.8	3433.2
3	0.0	503.5	1033.0	0.0	4557.3	21,831.6	2161.5
4	0.0	397.0	0.0	211.2	6942.6	6435.8	3690.9
5	258.9	723.2	0.0	4705.4	14,071.4	17,178.6	3062.5
6	0.0	0.0	0.0	52.8	61.6	96.8	88.0
7	35.2	739.4	1250.0	1250.0	8415.5	13,943.7	2852.1
8	0.0	0.0	928.6	1080.4	0.0	0.0	35.7
9	0.0	167.3	202.5	272.9	2464.8	16,980.6	3054.6

Mean percentage occurrence per m^2 quadrat for Rubus pensilvanicus for each MOFEP site by year. 1994-1995 represent pretreatment means, and 1997-2001 post-treatment means.

Site	1994	1995	1997	1998	1999	2000	2001
1	0.77	0.86	0.09	1.46	1.46	4.79	2.65
2	0.94	1.54	1.54	2.91	2.91	4.54	3.94
3	0.35	0.95	1.30	3.47	3.91	6.25	6.42
4	1.86	2.20	1.86	2.79	2.96	3.72	5.74
5	5.45	3.04	2.86	7.05	5.54	9.73	10.00
6	1.50	0.88	0.79	1.06	0.62	0.53	1.06
7	4.67	4.93	2.82	6.95	6.07	8.45	11.36
8	1.79	2.14	1.96	2.50	2.14	2.95	0.98
9	3.35	4.31	1.58	6.87	2.99	4.93	7.75

Scientific Outputs:

This is a short summary of a final report that was completed in 2003. We are currently working to wrap up data management and final analysis, with the view of completing a publishable manuscript sometime during FY 2006.

Research Plan for 2004-05:

Our research plan for 2004-2005 includes data management (cleaning remaining data sets), final data analysis, and manuscript preparation.

Hard Mast

Project Title: Acorn production on the Missouri Ozark Forest Ecosystem Project Study Sites

Team Members: Mark Johanson, Randy Jensen, Mike Hubbard, Larry Vangilder, Gary Sullivan

Project Objective:
Determine how even-age, uneven-age, and no-harvest forest management affect mast production in the Missouri Ozarks.

Key Findings (Pre-Treatment Only):
Production of sound mature acorns was highly variable among treatments, years, block, and ELT's.

The production of sound, mature acorns, DBH of oak trees and mean canopy area of oak trees was different among ELT's. Ridgetops were consistently the highest acorn producers, and upland waterways were consistently the worst acorn producers.

Red oak and white oak groups do not peak in the same year. In 1994, more than 90% of the sound mature acorns collected were of the red oak group. In 1993 and 1995 the white oak acorns made up a much higher proportion of the production.

Soundness of acorns was highly variable among species groups and among years. Soundness of red oak group acorns ranged from 9 percent on site 7 in 1993 to 68 percent on site 6 in 1994, and soundness of white oak group acorns ranged form 6 percent on site 7 in 1993 to 83 percent on site 9 in 1995.

Scientific outputs:
Vangilder, Larry D. 1997. Acorn Production on the Missouri Ozark Forest Ecosystem Project Study Sites: Pre-treatment Data p. 198-209. In: Brookshire, B. L. and. S. R. Shifley (eds.). Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. General Technical Report NC-192. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 378p.

Research Plan for 2004/5:
1. Continued data collection.
2. Re-inventory the overstory trees in the acorn plots. I would at least like to note if the trees are alive or dead. The last data collection on the trees was completed in 1997.

Design and analysis

Project Title: Developing a comprehensive statistical model for Missouri Ozark Forest Ecosystem Project

Team Members: Chong Z. He, Xiaoqian Sun, John Kabrick, Mike Wallendorf

Project Background:
The Missouri Ozark Forest Ecosystem Project (MOFEP) is a century-long, landscape-scale experiment to test effects of forest management practices on the flora and fauna of upland oak ecosystems. A wide array of ecosystem attributes has been studied on the MOFEP sites. More specifically, MOFEP includes 32 related projects of such diverse attributes as neotropical migrant songbirds, small mammal communities, herptofaunal communities, oak herbivore dynamics, leaf litter arthropod dynamics, genetic diversity of trees, armillaria distribution and root rots, coarse woody debris dynamics, vegetation composition and dynamics, acorn production, mechanical damage to forest by harvesting, microclimatic effects of harvesting, tree cavity abundance and density, lichen composition and dynamics, soil response and nutrient dynamics, and ecological landtype responses (Kabrick et al 1999).

The MOFEP experiment is laid out in a randomized complete block design. Nine sites that range in size from 772 to 1,271 ac are selected as experiment units. The nine sites are allocated equally to three blocks based on their spatial proximity to each other. Each of the management treatments (even-aged, uneven-aged, and no-harvest) is assigned randomly to three experimental sites in the each block (Brookshire and Dey 2000).

MOFEP was initiated in 1989. Pre-treatment data were collected through 1996, when the first series of harvest treatments were implemented. Post-treatment data have been collected since 1997 to the present. Sheriff and He (1997) presented three simple statistical models for analyzing MOFEP data. Model 1 (randomized complete block design) can be used to examine block and treatment effects. Model 2 (split-plot design) can be used to examine block, treatment, and ELT effects when sites are divided into different ELT levels. Model 3 (split-plot design with repeated measures) can be used to examine block, treatment, ELT, and year effects when the data are collected over years. To date, MOFEP data have been analyzed by these three models and some other statistical methods (such as regression models and principal components). The response variables are analyzed separately (i.e., one at a time).

The above statistical models (or methods), used for analyzing MOFEP data, are traditional statistical methods. These traditional statistical methods are simple and efficient for a single study with a large sample size and few response variables. However, the MOFEP sample size of nine is too small to efficiently test effects of forest management practices in many studies. Moreover, MOFEP consists of 32 different studies that each have one or more response variables. Therefore, there are about 80-100 response variables in MOFEP and traditional statistical models are not well-suited for studying the interrelations among so many ecosystem attributes. Most MOFEP studies collect spatial and temporal information on response variables. Some studies also collect spatial and temporal information on environmental variables. All the response and environmental variables are related to each other to some extent. The traditional statistical methods do not efficiently utilize spatial information or interrelationships among response and environmental variables. Using the spatial information and interrelationships among variables will increase the power to test multiple effects of forest management practice and to study the interrelation among ecosystem attributes.

In the recent years, many new statistical methods (such as spatial-temporal models, modern multiple testing, stochastic search variable selection, Bayesian model averaging, Bayesian hierarchical models, latent variable methods, and Markov Chain Monte Carlo methods) are developed to deal with complex models. Those new methods have been successfully used in biological, medical and genetic research. Adapting those new methods to MOFEP will enable us to develop a comprehensive statistical model for MOFEP by incorporating spatial-temporal effects and interrelationships among attributes.

Project Objectives:

1) To identify the response variables simultaneously affected by treatments;
2) To develop spatial-temporal models for important variables;
3) To develop a comprehensive statistical model for MOFEP that includes spatial-temporal effects and interrelationships among ecosystem attributes;

Key Findings:

We have just started working on this project. One Ph.D graduate student, Xiaoqian Sun, is working on the project starting from this semester (Fall 2004). Xiaoqian has been reading the literatures and getting familiar with the data sets.

We expect that the comprehensive statistical model will increase the power to test multiple effects of forest management practices and to study the interrelation among ecosystem attributes. It will also stimulate cooperation among principal investigators, generate new research ideas, and provide information to adapt the sampling designs for the next data collection period. These proposed methods once developed will be an important component in making MOFEP the most integrated ecosystem study to date.

Plan for 2004-2005:

1. Transfer data from GIS systems to Splus systems so that the new statistical models can be developed and tested by using Splus;
2. Conduct simultaneous multiple tests to identify the treatment effects;
3. Build the comprehensive statistical models;
4. Developing cooperative relationships with other interested PI's.

Forest Interior Birds

Project Title: Effects of selected timber management practices on forest birds in Missouri oak-hickory forests

Team Members: Rick Clawson, John Faaborg, Paul Porneluzi

Project Goal:
The goal of the forest bird component of MOFEP is to understand the relationships between forest management and bird populations. Many bird species, including some Neotropical migrant species that are facing long-term population declines, depend on forest ecosystems that are routinely managed for timber resources. Identifying and understanding the mechanisms that link forest management to bird population processes will help scientists sustain species that use these ecosystems. The reliability of our conclusions is greatly improved by the rigorous experimental design of MOFEP. We are directly monitoring the impacts of forest management on avian demography and exploring these relationships at expanded temporal and spatial scales. Other research into the impact of forest management on bird populations is frequently conducted at limited spatial and temporal scales that are not relevant to maintenance of bird populations or communities, and many studies lack rigorous experimental designs with adequate replication and randomization. Furthermore, many researchers measure only species' abundance and habitat use, but these patterns may not reflect reproductive success or habitat quality.

Project Objectives:
The overall, long-term objectives of the MOFEP bird study are:
1. To determine differences in breeding densities of selected a) mature forest and b) early-successional forest songbirds in forest managed by even-aged, uneven-aged, and no-harvest methods.
2. To determine rates of nest parasitism, nest predation, and reproductive success for these songbirds in forest managed by even-aged, uneven-aged, and no-harvest methods.
3. To provide an educational training ground in field biology for a diverse and talented group of students.

Key Findings:
In Clawson *et al.* (1997,) we published the results of 5 years of pre-treatment data collection. This established the baseline for evaluating the impacts of the forest harvest. In Clawson *et al.* (2002) and Gram *et al.* (2003,) we compared 5 years of pretreatment (i.e., before timber harvest) and 3 years of post-treatment data on bird species density and reproductive success. We assessed these changes at a large spatial scale relative to timber harvest (i.e., density was evaluated at the spatial scale of study site rather than as local density within a harvested forest stand.) We focused our analyses on five mature forest species (Acadian Flycatcher, Kentucky Warbler, Ovenbird, Worm-eating Warbler, and Wood Thrush) and six early successional species (Blue-winged Warbler, Hooded Warbler, Indigo Bunting, Prairie Warbler, White-eyed Vireo, and Yellow-breasted Chat.) These are the species that are most abundant and for which we acquired the most reliable density and nest success data.

In summary, mature forest bird populations declined as trees were removed, but significant changes in nest predation and brood parasitism did not occur. In addition, openings associated with timber removal provided habitats for early successional species. Responses tended to be species specific. Notably, at least two species generally classified as mature forest species (Wood Thrush and Kentucky Warbler) increased on disturbed sites relative to controls and appeared to prefer mature forest that included some disturbance within the forest matrix. Furthermore, some early succession species (Yellow-breasted Chat and Prairie Warbler) preferred the large clearings that characterized even-aged management, whereas other species would enter any clearing larger than a mature tree. In addition, bird density increased as opening size increases. When we estimated productivity by multiplying density and nesting success, we found pre- to post-treatment changes that suggested future effects on productivity, particularly for Ovenbird and Wood Thrush. Estimated productivity of Wood Thrush increased in even-aged treatments because both density and nesting success increased after treatment. For Ovenbirds, a decline in both density and reproductive success led to a decrease in estimated productivity in even-aged treatments. Finally, we suggested that a mixed strategy of timber management may be necessary to support the full range of breeding birds in this region.

Throughout the project, we have shared resources and data with other researchers. We used data collected on the MOFEP bird project to compare with data collected in fragmented Missouri forests to examine the influence of both local habitat and landscape variables on avian species abundance (Howell et al. 2000). This enabled us to suggest that landscape variables are significant predictors of abundance for many bird species and that resource managers should consider multiple measures of landscape sensitivity when making bird population management decisions. In Howell et al. 2004, we compared the effectiveness point count and spot-map methodologies in estimating changes in bird abundance. We found that point counts were significantly correlated with spot-maps and could be relied on to detect relatively large changes in abundance, such as the changes that occurred following the MOFEP forestry treatments. Other examples of collaboration include the following: Dr. Robert Ricklefs and his research associates from the University of Missouri-St. Louis have accompanied our interns while mist-netting to acquire blood samples from the birds as part of a large scale parasitology study. Dr. Frank Thompson and associates at the North-Central Forest Experiment Station are using our nest data to test and evaluate new models of nest predation. Graduate students from the University of Missouri-Columbia and University of Arkansas, have used MOFEP sites for research with Wood Thrush, Hooded Warblers, and Indigo Buntings.

We are completing a more detailed spatial analysis of the forest bird response to even-aged management following the first harvest rotation (Wallendorf *et al.*, in manuscript.) The purpose of this analysis is to characterize the extent to which species respond in the habitats outside the actual clearcuts, including timber stand improvement areas. Preliminary results show that Ovenbird density was significantly reduced in the 100 m buffer surrounding the clearcuts and also in the stands receiving TSI. As a result, the impact of this type of forestry was much greater than would be expected by the 10-15% of the site that was received direct clearcutting. Acadian flycatcher density also was significantly reduced within the TSI stands. Several species significantly increased in density in the 100 m buffer surrounding clearcuts. These include two mature forest bird species (Wood Thrush and Kentucky Warbler) and three early succession species (Indigo Bunting, Hooded Warbler and Yellow-breasted Chat.) Results of this analysis will generate new hypotheses to be addressed in the future, particularly hypotheses regarding the causes of each species response and the effect of clearcut shape.

Since 1991, the forest bird study has been an exceptional training ground for new field biologists. Over the past 14 years, this approach has attracted 246 diverse and talented undergraduates who have gone on to successful graduate and professional careers. Our interns have come from over 90 different undergraduate institutions; 9% are under-represented minorities; 45% are women; and at least 54 have gone on to graduate and professional degrees.

Research Plan for 2005:
Future research will continue to document the dynamics of the forest bird response to forestry. At this stage of the experiment, the density of most species responding favorably to disturbance is reaching a plateau or beginning to decrease. Forest birds will return to the harvested stands in a species-specific manner. Following these dynamics is important to create predictive models of the shifts in species abundance that will occur in response to the forestry treatments. Forest structure will change with additional harvesting during later stages of the project and this could have ramifications for both avian densities and reproductive success.

We have applied for a Research Experiences for Undergraduates grant from the National Science Foundation. If the bird study is selected for funding, we will put 12 interns into the field to continue collecting data on all nine study sites. We will spot map birds, find and monitor nests, and mist net and band birds, using the protocols from the 2001-2003 field seasons.

Scientific Outputs:

Publications
Clawson, R. L., J. Faaborg, and E. Seon. 1997. Effects of selected timber management practices on forest birds in Missouri oak-hickory forests. Pp. 274-288 *In* Brookshire, B. L. and S. R. Shifley (eds.,) Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: An Experimental Approach to Landscape Research. North Central Forest Experiment Station. General Technical Report NC-193.

Clawson, R. L., J. Faaborg, W. K. Gram, and P. A. Porneluzi. 2002. Landscape-level effects of forest management on bird species in the Ozarks of southeastern Missouri. Pp. 147-160 *In* Proceedings of the Second Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment Results of the Landscape Experiment. North Central Forest Experiment Station. General Technical Report NC-227.

Gram, W. K., P. A. Porneluzi, R. L. Clawson, J. Faaborg, and S. C. Richter. 2003. Effects of experimental forest management on density and nesting success of bird species in Missouri Ozark forests. Conservation Biology 17:1324-1337.

Gram, W. K., V.L. O. Sork, R. J. Marguis, R. B. Renken, R. L. Clawson, J. Faaborg, D. K. Fantz, J. Le Corff, J. Lill, and P. A. Porneluzi**.** 2001. Evaluating the effects of ecosystem management: A case study in a Missouri Ozark forest. Ecological Applications 11:1667-1679.

Howell, C. A., S. C. Latta, T. M. Donovan, P. A. Porneluzi, G. R. Parks, and J. Faaborg. 2000. Landscape effects mediate breeding bird abundance in Midwestern forests. Landscape Ecology 15:547-562.

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Kabrick, John M.; Renken, Rochelle B.; Kurzejeski, Eric W.; Jensen, Randy G.; Gram, Wendy K.; Clawson, Richard L.; Porneluzi, Paul A.; Faaborg, John; Fantz, Debra K.; Grabner, Jennifer; Johanson, Mark. 2004. The Missouri Ozark Forest Ecosystem Project: Findings from Ten Years of Evaluating Management Effects on Forest Systems In: Yaussy, Daniel A.; Hix, David M.; Long, Robert P.; Goebel, P. Charles, eds. Proceedings, 14th Central Hardwood Forest Conference; 2004 March 16-19; Wooster, OH. Gen. Tech. Rep. NE-316. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 484-496.

Thompson, F. R. III, J. D. Brawn, S. Robinson, J. Faaborg, and R. L. Clawson. 2000. Approaches to investigate effects of forest management on birds in eastern deciduous forests: How reliable is our knowledge? Wildlife Society Bulletin 28:1111-1122.

Wallendorf, M., R. L. Clawson, P. A. Porneluzi, J. Faaborg, and W. K. Gram. *In manuscript.* Avian response to clear cutting and timber stand improvement in Missouri Ozark forest.

Results from the bird study were communicated in an interview that John Faaborg gave to Environmental Review, March 2004 (available at http://www.environmentalreview.org/vol11/vol11no3.pdf.)

Presentations

Clawson, R. 2003. Effects of Experimental Forest Management on Density and Nesting Success of Bird Species in Missouri Ozark Forests. Presented at the annual meeting of The Wildlife Society in September 2003.

Clawson, R. 2003. Oak Decline – Possible Effects on Birds and Bats. Presented at the Oak Decline Workshop at the Natural Resource Conference in January 2003.

Clawson, R. 2002. Missouri Ozark Forest Ecosystem Project Bird Projects. Presented at the Forest Avian Ecology and Management Workshop in July 2002.

Clawson, R. 2000. Management of Missouri Forests for Birds. Presented to MDC Private Lands Division managers as part of their orientation and training in April 2000.

Clawson, R. 1996. The Missouri Ozark Forest Ecosystem Project Bird Study. Presented at the Forest, Fish, & Wildlife Conference in February 1996.

Clawson, R. 1993. The Missouri Ozark Forest Ecosystem Project Bird Study. Presented to MDC Wildlife Division managers as part of a workshop in September 1993.

Clawson, R. 1992. The Missouri Ozark Forest Ecosystem Project Bird Study. Presented as a poster at the National Training Workshop on Status and Management of Neotropical Migratory Birds in September 1992.

Small Mammals and Hepertofauna

Project Title: Short-term responses of small mammal and hepertofauna communities to forest management within Missouri Ozark Forest Ecosystem Project sites

Team Members: R. Renken, D. Fantz

Original Project Objectives:
Amphibian and Reptile Research

1) Determine if even and uneven-aged forest management have short-term (3 years after cutting) effects on the species composition, species richness, and relative abundance of herpetofaunal communities inhabiting state forests in southern Missouri's Ozark oak-hickory forests during FYs 1992 - 2000.

2) Determine if selected forest habitat characteristics and environmental factors are related to the presence and relative abundance of selected amphibians and reptiles inhabiting state forests in southern Missouri's Ozark oak-hickory forests during FYs 1992 - 2000.

3) Determine if even-aged forest management has a short-term (3 years after cutting), small scale effect on the species composition, species richness, and relative abundance of herpetofaunal communities inhabiting cuts and adjacent, uncut forest (50m and 200m from treatment edge) on state forests in southern Missouri's Ozark oak-hickory forests during FYs 1992 - 2000.

Small Mammal Research
1) Determine if even and uneven-aged forest management have a short-term (2 years after cutting) effect on the species composition, species richness, and relative abundance of small mammal communities inhabiting state forests in southern Missouri's Ozark oak-hickory forests during FYs 1993 - 2000.

Key Findings:
Amphibian and Reptile Research
We determined that the forest management treatments of no-harvest, even-aged, and uneven-aged management did not affect the species composition, species richness, and overall amphibian and reptile relative abundance in the first few years after the first entry harvest (Renken and Fantz 2002). We also learned that at the landscape – scale for south and west facing slopes, and north and east facing slopes, we did not detect an immediate effect of treatment on the relative abundance of most of the 13 focal species (seven amphibian and six reptile species) of interest (Renken et al. 2004). We detected an effect of treatment on only one species, *Bufo americanus*. The abundance of *B. americanus* declined in all treatments in the post-treatment period, but the detected effect was largely due to the steep decline in abundance of toads on no-harvest sites. Toad abundance on harvested sites may not have declined as much as on no-harvest sites because of a possible increase in invertebrate density, a potential source of food, in cuts. We also suspect that a regional drought may have caused the decline of toads on all treatments, thus

leading us to think an environmental event may have had a greater effect on toad abundance than treatments in the immediate post-treatment period.

In the portion of the project where we examined the effect of distance from clearcut (within clearcuts, and 50m, and 200m from clearcut edges) on amphibian and reptile abundance, we detected differences in abundance for one amphibian and two reptile species of the 13 focal species (Renken et al. 2004). *Ambystoma maculatum* abundance declined within clearcuts. The decline in *A. maculatum* abundance within cuts was not surprising given the body of literature that describes the effect of tree harvest on amphibians (deMaynadier and Hunter 1995). *Sceloporus undulatus* abundance increased within clearcuts, yet did not change 50 and 200m from clearcuts. Environmental conditions within clearcuts may have favored *S. undulatus* populations resulting in a detected increase in abundance. *Scincella lateralis* abundance initially increased in uncut forest 50m and 200m from clearcuts, while *S. lateralis* abundance remained unchanged within clearcuts. The increase in *S. lateralis* abundance may also have been due to enhanced environmental conditions for *S. lateralis* in the uncut forest surrounding clearcuts.

Small Mammal Research
Even-aged management, and to a lesser extent uneven-aged management, appeared to provide conditions that dampened a natural decline in *Peromyscus* spp. numbers during the post-treatment period (Fantz and Renken, in press). While mice abundance declined from pre- to post-treatment on no-harvest sites, mice abundance remained the same on even-aged sites. Mice abundance on uneven-aged management sites declined slightly from pre- to post-treatment periods. We suspect the increase in cover, food (as evidenced by the increase in the amount of berries), and coarse woody debris on even-aged, and to a lesser extent, uneven-aged management sites, possibly increased the number of nest sites, travel routes, and invertebrates for mice.

Research Plan for 2004/2005:
In the later part of FY2005, I plan to submit a proposal to support sampling amphibian, reptile, and small mammal sampling on MOFEP sites during calendar years 2007-2010, a period of four years prior to the next reentry in 2011. I will submit the proposal within the Missouri Department of Conservation's project review system. Prior to submitting the proposal, I plan to consult with biometricians and ecologists to determine if methods for sampling should be modified to better meet project objectives.

Scientific Outputs:
Publications
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Renken, R.B., S.C. Richter, and W.K. Gram. 2002. Landscape and local scale effects of forest management on amphibians and reptiles in Missouri Ozark forests. Poster presentation at the joint meeting of the American Society of Ichthyologists and Herpetologists, the Herpetologists' League, and the Society of the Study of Amphibians and Reptiles. Kansas City, MO.

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Ecosystem Project. Presentation given at the Second Missouri Ozark Forest Ecosystem Project Symposium: post-treatment results of the landscape experiment. St. Louis, MO.

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Oak Herbivore Fauna

Project Title: Impacts of alternative timber harvest practices on canopy and understory leaf-chewing Quercus herbivores

Team Members: Robert J. Marquis and Rebecca E. Forkner

Overview and objectives:
Insect herbivores are major components of Ozark forest communities, both in terms of their ecological and economic role, and their diversity. Because oaks (*Quercus* spp.) dominate Ozark forests, leaf damage by insects that feed on *Quercus* potentially could affect forest productivity. Furthermore, these insects are important components of forest food webs, providing food resources for birds, small mammals, and parasitic insects and nematodes. Characterizing the impacts of logging treatments on these insects, therefore, is essential to developing mechanistic explanations for treatment effects on plant productivity, vertebrate abundance, as well as nutrient cycling and forest regeneration. Our basic objective is to document the impacts of the forest management treatments on the abundance, richness, and community structure of leaf-chewing herbivores feeding on *Q. alba* and *Q. velutina* in the canopy and the understory by conducting censuses four times during each annual growing season.

Key Findings:
Over ten years, we have encountered 260 species of leaf-chewing herbivores. Eighty-eight percent of these species are larval Lepidoptera. These communities show predictable seasonal turnover in species identity. Diversity of leaf chewing herbivores is generally greatest in May after budburst, when oak insect communities are dominated by species of Gelechiidae, Noctuidae, and sawflies. Diversity is also high in August, when species of Limacodidae and Notodontidae contribute to peaks in species richness. Timing of peak density, however, varies among months within years, but tends to be highest on *Q. velutina* in May and highest on *Q. alba* mid and late season. Although insect abundances are generally lower in the canopy compared to the understory, some species appear to be canopy specialists (e.g., *Psilocorsis reflexella*, *Stigmella* sp.). Parasitism rates on oak herbivores are also highest in May. Our data describing diversity and seasonal variation in leaf-chewing insects are uniquely important in that they are the only data set of this kind for a temperate forest. These data also provide invaluable natural history information to be included in a photographic guide to the Lepidoptera larvae that we have reared successfully on oaks.

Impacts of timber extraction on oak herbivore richness, abundance, community structure, and accumulation of new species
Sizeable, but non-significant, pre-treatment variation in understory species richness (# of species/ m^2 leaf area) on *Q. velutina* existed: uneven-aged sites had 26% fewer species than no harvest management (control) sites. Following timber harvest, *Q. velutina* in the remaining matrix of uneven-aged sites had 17% fewer and even-aged sites 8% more species compared to trees in control sites. However, the significant treatment effect was between uneven- and even-aged sites rather than between treated sites and controls. These results suggest that logging elevated understory species richness on *Q. velutina* in untreated areas of uneven- and even-aged sites. Understory species richness on *Q. alba* did not vary among sites pre-treatment, but uneven-aged

sites had 32% fewer species compared to trees in control landscapes post-treatment from 2000 – 2003, suggesting a delayed negative impact on species richness. Harvesting treatments did not alter understory total insect density or community structure in the unlogged habitat for either oak species. Understory community structure of herbivores on *Q. alba* and *Q. velutina* within clearcut gaps differed from that of unharvested areas of EAM sites. Furthermore, both understory richness and total insect density on *Q. velutina* within clearcut gaps were reduced compared to intact stands. Timber extraction did not alter species richness of canopy herbivores. MOFEP blocks vary in species richness, with richness being higher in Block 2 (older forest) and lowest in block 3 (youngest forest) for both oak species. Moreover, species richness and total insect density were higher in general on north- and east-facing slopes compared to south- and west-facing slopes. Rates of accumulation of new species follow the same patterns as species richness: species accumulation rates were highest for *Q. velutina* in EAM sites and lowest in UAM sites, whereas for *Q. alba* rates of accumulation were marginally lower in UAM sites.

Impacts of timber extraction on level of defoliation by leaf-chewing herbivores
The cumulative percentage leaf area removed (% LAR) did not differ among logging treatments for understory *Q. alba* and *Q. velutina*, but there was a significant treatment by block interaction. In blocks 1 and 3, defoliation was 2 and 4% higher, respectively, for *Q. alba* and *Q. velutina* trees in UAM compared to NHM and EAM sites, but in block 2, percent LAR was highest for trees in NHM sites. Percent LAR differed significantly among blocks for understory trees: levels of % LAR were 14.4 ± 1.0 % in block 1 compared to 18.0 ± 1.0 % blocks 2 and 3. Additionally, understory foliage of *Q. alba* and *Q. velutina* growing on slopes having south- and west-facing aspects had lower levels of defoliation (17.8 and 12.4 ± 1.0 % LAR, respectively) compared to trees growing on north- and east-facing aspects (20.3 and 17.0 ± 1.0 % LAR, respectively). Furthermore, there was a significant block × slope interaction indicating that levels of defoliation on understory trees were greatest in block 2 for ELT 18 (north and east-facing slopes) but greatest in block 3 for ELT 17 (south and west-facing slopes). Levels of defoliation in the canopy did not differ among treatments or between oak species, but levels of defoliation in the canopy were lower than understory levels (canopy 11.1 ± 0.7 %, understory 16.9 ± 0.5 %).

Impacts of timber extraction on oak chemistry
To determine if UAM and EAM impacted levels of foliar phenolics (putative anti-herbivore plant defenses) in white and black oak, we quantified the levels of condensed tannins (CT) and total phenolics in the leaves of canopy and understory trees. In the understory, a significant oak × treatment interaction effect indicated that total phenolics levels were slightly elevated in *Q. velutina* trees in UAM relative to trees in NHM and EAM sites but lower in *Q. alba* trees in EAM relative to trees in UAM and NHM sites. Treatment by block interactions for understory total phenolic concentrations indicated that logging did affect foliar chemistry but only in older forests. In the canopy, treatment by block interactions indicated that treatments altered plant chemistry only for trees in block two, where CT concentrations were elevated in trees within UAM and EAM sites relative to NHM for *Q. alba*, but elevated in UAM and reduced in EAM relative to NHM for *Q. velutina*. Understory trees of both species had higher levels of both CT and total phenolics when growing on slopes having south- and west-facing aspects. Our results indicate that timber harvests, even at low levels of extraction (10% biomass removal), altered concentrations of foliar polyphenolics and that the effects of logging on phenolics were dependent on blocking factors.

Impacts of timber extraction on dung beetles
Twenty species of dung beetles were sampled in the MOFEP sites in 2003. To determine the effects of harvesting at the local level, a linear transect for each of three clearcuts per EAM site was established from clearcut edge, 60 m into the clearcut and 60 m into the forest. Average richness and abundance were lower in clearcuts compared to edge and forest samples. Pooled species richness was greater for clearcuts suggesting greater β–diversity in that habitat. To compare treatment effects at the landscape level, beetles were sampled in closed canopy (all three treatments) and clearcuts (EAM), group cuts (UAM), and natural tree falls (NHM). Even-aged management increased beetle abundance compared to UAM and NHM by 50%, while canopy cover had no effect. There were no treatment effects at the landscape level on species richness.

Long-term succession of herbivores in forests spanning three hundred yeas in age
We sampled insect abundance on undestory *Q. alba* in a chronosequence of forests from 5 to 300 years of age from the Potosi region to the Current River watershed. Insect species richness and abundance increased with age for the August but not the May insect fauna. In addition community structure changed with forest age, and density was lower on south- and west-facing slopes in the August census.

Bird-insect correlation analysis
We compared insect abundance with bird abundance at the stand level (circular plots of 200 m radii) for the years 1993-95 and 1997-2000. Bird abundances were much more spatially consistent over time than insects. At the community level, insect abundance in 1994 summed over white and black oak was negatively correlated with bird abundance in 1994, suggesting that birds reduce the number of insects at the local level. Other weaker correlations of the same sign, were found in the years 1993-1995, but none post-treatment. Significant correlations were found for insects on white oak alone but none for black oak, suggesting the interactions between insects on white oak and birds were driving the community-level pattern. Acadian Flycatcher abundance was negatively correlated with abundance on insects in the same year or following year, while ovenbird abundance was positively correlated. There were few or no significant correlations for the other birds sampled (Red-eyed Vireos, Worm-eating Warblers, Kentucky Warblers, and Wood Thrushes). Overall these analyses suggest that the community of insectivorous birds affected the abundance of insects locally within the same year but only infrequently. Abundance of Acadian Flycatchers in 1993 may have had a negative effect on insect abundance in 1994.

Research Plan for 2004-5:
We will continue with sampling white and black oak insect communities in the understory and canopy, six stands per site (all 9) in the understory and 2 stands per site (6 northern) in the canopy, four times during the year.

Population dynamics
In general, we know relatively little of the factors that influence or regulate populations of forest insect herbivores. This is especially true for those species that do not reach outbreak levels. Our lack of knowledge about this aspect of insect ecology stems largely from an absence of long-term data on insect abundances. Long-term data will reveal the amplitude and frequency of

existing population cycles. Initial data from our censuses suggest that some commonly encountered herbivores do exhibit population cycles (*Lochmeaus manteo* and *Lithophane attenata*), whereas others do not (*Acronicta increta*). However, in no case have we observed one entire population cycle. To establish these patterns, as well as the potential impacts of logging on population dynamics, continuous abundance data are required. We anticipate sampling every year through and beyond the second round of cutting. Our major objective would be to describe the population dynamics of the leaf-chewing herbivore species and conduct analyses to reveal patterns of density dependence and factors that might be driving such density dependence.

Scientific Outputs:

Presentations

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Leaf Litter Arthropod

Project Title: The impact of logging on the distribution and abundance of leaf litter arthropods within Missouri Ozark Forest Ecosystem Project sites

Team Members: Jan Weaver

Project objectives: Investigation of leaf litter arthropod communities to find:

a) what is out there?
b) what are the significant factors influencing numbers, mass, richness and diversity of this community?
c) what can this community tell us about communities in general?
d) what effect does logging have on leaf litter arthropod communities?

Key Findings:
What is out there? What are the significant factors influencing numbers, mass, richness and diversity?
<u>The leaf litter community has lots of individuals, a respectable amount of mass, and lots of species. Numbers, mass and richness are influenced by the slope and aspect of a plot.</u>
For 36 plots where leaf litter was collected in 1993, there was an average of 16,150 arthropods (>0.2mm) and 11.7 g of arthropod biomass per square meter, and a total of 547 morpho species in 22 orders. Collembola were the numerically dominant taxa, an oribatid mite specializing on downed dead wood was the numerically dominant mite, and a mesostigmatid mite and a pseudosorpion were the dominant arthropod predators. There was a significant positive correlation between mass and richness, a significant negative correlation between numbers and slope, and NE facing plots had higher numbers, mass and richness, while SW facing plots had higher diversity.

What can this community tell us about communities in general?
<u>The relative number of species in a taxon varies with the scale of observation.</u>
Mites are the most speciose group at very small scales, but because the same species are found throughout the forest, their relative richness goes down as you expand the scale of observation. Beetles, on the other hand, present only one or a few species at a small scale of observation, but because there are different beetles at every site, their relative richness is greater at larger scales. Therefore, using indicator taxa to compare the richness of entire communities may be problematic unless the scale of observation is specified and held constant.

<u>Patterns in species size in this community mirror patterns for world-wide patterns of species size.</u>
Robert May found a mode at 1-3 mm when he plotted species richness vs. size for all known animals. We plotted data for animals between 0.25 and 5 mm and found a pattern similar to May's with a mode at the 1-3 mm size class. So the global pattern in species size distribution appears to hold even for a much smaller sample of the global fauna, and for one that includes a range of much smaller animals than May had to work with.

What effect does logging have on leaf litter arthropod communities?
<u>Logging may have a strong, indirect, but transient effect on ant numbers.</u>

The experimental treatments, logging of forest compartments, was not replicated in this study. However, we can make statements about Before/After and Control/Treatment numbers of ants and ant species. Ant numbers in pre-treatment forests ranged from 10 to 60 ants per plot, but did not vary significantly among treatments. After logging in 1996, average ant numbers in the two logged forests, both even-aged and uneven-aged, were approximately 1/2 the number in control forest in 1997 and 1998. By 1999, ant numbers in both logged forests were virtually identical to numbers in the control. Because only a small number of plots were directly disturbed by logging, it appeared that if logging were responsible for the decline, it had a strong, indirect, but transient effect on forest ant communities.

<u>The effect of logging on ant species richness depends on plot aspect and method of logging.</u>
Keeping in mind this research is not a direct test of the effects of logging, differences among ant species communities, pre and post logging, varied with plot aspect and with the method of logging. On NE facing plots, there was no change in ant species richness the first year after logging, but the second year after logging, richness was dramatically lower in both even-aged and uneven-aged plots compared to the control and to pre-logging values. On SW facing plots, the even-aged plots showed strong declines the first year after logging compared to control, uneven-aged and pre-logging even-aged plots. In the second year after logging, all three sets of SW plots, including the control, showed values lower than pre-logging values. By the third year all the SW plots had values higher than most of the pre-logging samples.

<u>Mid-Level ant species appear to be more affected by logging than common ant species.</u>
Less common species are likely to have more restrictive niche requirements than common species, so they are more likely to be affected by changes in their environment, even apparently small ones. I computed the correlation between presence/absence data for the three years pre-logging and three years post-logging for 15 species of ants found at least once in a seven year period in NE plots in each of three forest compartments. Then I sequentially removed ant species (most common to tenth most common species) to see what effect removing common species had on the correlation. I expected that if logging were disruptive, it would be more likely to show up as an impact on less common or mid-level species because they would have more restrictive habitat requirements than common species.

When the control pre and post years were compared, the correlation between ant presence/absence data only dropped from 0.9 to 0.7 even after the 10 most common species had been removed. This indicates that species similarity is "deep" and that the pattern can persist for at least 7 years in undisturbed forest.

For the even-aged forest on the other hand, the correlation dropped from 0.7 to less than 0 by the removal of the 7th species. This indicates a "shallow" similarity between the pre and post-logging forests. You can still find the common ants after logging, but the mid-level species have disappeared, or new species have moved in where they weren't before.

For uneven-aged forests, the correlation started at 0.7 and had only dropped to 0.6 by the removal of the 8th most common species. In other words, the forest under uneven-aged management retained mid-level as well as common species after cutting, or had fewer new species move in.

Scientific Outputs:

Publications

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Weaver, J. C. and S. Heyman. 1997. The distribution and abundance of leaf litter arthropods. In: B. Brookshire and S. Shifley (eds.) Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: An Experimental Approach to Landscape Research. USDA/USFS/MDC.

Presentations

Weaver, J. C. 1994 "Estimating species diversity" (Presentation), Univ. of Tenn., Knoxville TN.

Weaver, J. C. 1995 "Patterns in Leaf Litter Communities" (Presentation) 22nd Natural Areas Conference, Little Rock AR.

Weaver, J. C. and S. Heyman 1998 "Patterns of Species Size in a Leaf Litter Community" (Poster) Am Soc Limn Ocean/Ecol Soc Am Joint meeting, St. Louis, MO

Weaver, J., S. Heyman, R. Feldman and N. Ekpo. 2000 "The Impact of Logging on Ant Communities in the Ozarks" (Poster) 2000 Missouri Academy of Sciences. Meeting, Columbia MO

Weaver, J. C. and S. Heyman "The Impact of Logging on Ant Species Diversity" (Poster) 2001 AIBS Meeting, Washington D.C.

Weaver, J. 2004 "Diversity Patterns in Space and Time Across a Forested Landscape" (Presentation), Central States Entomological Society Meeting, Lincoln NE

Research Plans for 2004-5:

a) Sort samples from June 2004 into major taxonomic groups - July, August 2004

b) Identify, count and measure ant species from the 2004 samples - August 2004 – May 2005

c) Update the mite species identification list – ongoing

d) Collect and extract leaf litter from all 36 plots - June 2005

Stump Sprouting

Project Title: Stump sprouting potential of oaks in Missouri Ozark forests managed by even- and uneven-aged silviculture

Team Members: Daniel C. Dey, Randy Jensen, Johann Bruhn, John Kabrick

Project Background:
Oak stump sprouts are important in obtaining adequate oak regeneration. In young stands, stump sprouting may account for the majority of the reproduction. In older stands, stump sprouts can supplement advance reproduction populations to ensure the adequacy of oak in the new forest. Managers need to be able to predict the contribution of stump sprouts to the overall population of oak reproduction to judge whether (1) reproduction is adequate, (2) artificial regeneration by planting or direct seeding is needed to supplement natural reproduction, (3) competition control is needed to maintain oak in a free-to-grow state, or (4) harvesting should be delayed to give time for the development of large advance reproduction. The contribution of oak stump sprouts to oak regeneration potential is predictable and estimates based on tree, stand and site characteristics can be made before harvesting.

We evaluated stump sprouting potential of white oak, black oak and scarlet oak in relation to tree age, stem diameter and overstory density in Ozark forests managed by even-aged and uneven-aged silvicultural systems. In eastern North America, few studies have evaluated the influence of a forest canopy on the potential of hardwood stumps to sprout and contribute to regeneration. The Missouri Ozark Forest Ecosystem Project (MOFEP) provides an opportunity to study oak stump sprouting in relation to tree characteristics and residual overstory density resulting from various regeneration methods.

Key Findings:
One growing season after the clearcut, single-tree and group selection harvests on MOFEP (1996), we measured sprout growth on 701 stumps of white oak (*Quercus alba* L.), scarlet oak (*Q. coccinea* Muenchh.) and black oak (*Q. velutina* Lam.). Stumps were selected from plots (primarily on Ecological Land Types 17 and 18) within uneven- and even-aged compartments. Stumps averaged 9.3 inches (23.6 cm) in diameter (range 1.7 inches to 33.3 inches [4.3 to 84.5 cm]) and 61 years in age (range 38 to 169 years). One year after harvesting, 78% of the oak stumps produced a live sprout. Stump sprout frequency was high for small diameter and young trees, regardless of species. However, sprouting probability declined more rapidly with increasing stump diameter or age for white oak than it did for scarlet oak and black oak. Scarlet oak and black oak produced more (mean = 12 stems) sprouts per stump than white oak (mean = 8 stems). Overstory density (e.g., clearcut vs single-tree gaps) had no detectable effect on oak stump sprouting probability or on the number of sprouts per stump. However, increasing overstory density reduced the height of the tallest stem in each stump sprout clump. The tallest stem within a sprout clump averaged 2.8 feet (0.85 m) in the single-tree selection treatment compared to 4.0 feet (1.2 m) in the clearcut treatment. Sprouting potential, height of the dominant sprout, and sprout clump density decreased with increasing stump diameter and tree age for all species regardless of overstory density.

In this study, we demonstrated that stem diameter and age are primary factors that determine the probability of sprouting, density of sprouts and height growth of the dominant sprout for individual trees. We also noted that sprouting potential and sprout growth varies by oak species.

Overstory density is important in determining long-term survival of oak stump sprouts and success of oak recruitment into the overstory. Further monitoring of stump sprouts in this study will provide valuable information on their contribution to oak regeneration in stands managed by uneven-aged management, and will provide a quantitative basis for assessing the fate of oak stump sprouts developing under a partial forest overstory. Managers can use these results to help determine when uneven-aged management is appropriate and to manipulate stand stocking to promote oak reproduction and recruitment.

Recently funded research: Re-Assessment of Oak Stump Sprout Growth and Survival, Accounting for Armillaria Root Disease-Related Oak Decline

Bruhn, Dey, Jensen, Kabrick
Funded by U.S. Forest Service, North Central Research Station

It has been approximately 8 years since the first MOFEP harvest. Dey and Jensen (2002) sampled 701 oak stumps following that harvest for assessment of stump sprouting potential under even- and uneven-aged forest management. In the process of our studies, during 2002 we began finding oak stump sprouts killed by Armillaria root disease. This led us to question the simplicity of the proposed models of stump sprout production based on stump size and age, as larger and older stumps are likely to be carrying greater *Armillaria* infection levels than smaller or younger stumps at the time of their harvest. We also noted the asymmetrical distribution of stump sprouts around the circumference of many stumps, and preliminary observations indicated that the circumferential distribution of stump sprouts is often initially related to the circumferential distribution of *Armillaria*-infected buttress roots. To the extent that all this is true, oak stump sprout production and long-term survival are likely to reflect *Armillaria* infection levels, and models of sprouting potential may overestimate sprout production and survival in stands vulnerable to decline in the presence of *Armillaria*.

Therefore, we will re-visit a large representative sample of the stumps previously measured and aged (Dey and Jensen 2002), to re-evaluate sprout survival and growth, to assess the presence and activity of *Armillaria* species in the supporting stumps, and to re-model stump sprout production and survival to reflect the presence or absence of *Armillaria* species on the stumps. This work is very timely because the deteriorating condition of the 1996 MOFEP stumps will make it increasingly difficult over time to obtain useful *Armillaria* cultures for speciation.

Recently, oak decline is widespread in the Ozark Highlands of Missouri and Arkansas, resulting in greatly reduced productivity of these forests due to regeneration failures, shifts in species composition and understocked stand conditions. Oak decline is a disease syndrome caused by interactions among predisposing factors (site quality, tree age), inciting factors (*e.g.*, drought, frost, insect wood borers and defoliators, and harvest activity) and contributing factors (*e.g.*, *Armillaria* root disease). Oak decline mortality episodes occur periodically in southern Missouri, and appear to affect species in the red oak group more severely than species in the white oak group. The role of Armillaria root disease in Ozark oak decline has only recently been studied, due to the largely cryptic nature of Armillaria species.

Three species of *Armillaria* root decay fungi have been identified in upland forests of the Ozark Mountains. Given that the most aggressive of these species (*A. mellea*) is ubiquitous in upland Ozark forests, and that *Armillaria* species can survive in the stumps and root systems of infected or killed trees for decades, it is reasonable to suspect that *Armillaria* species may also contribute to the death of significant numbers of sprouts originating from stumps of infected trees. Preliminary observations suggest that this is the case, but the nature and extent of this phenomenon need to be characterized and evaluated. Because stump sprouts have been considered the most competitive and significant form of oak reproduction in these forests, silvicultural predictions of stand regeneration have been based on models of stump sprout regeneration. Studies on stump sprout regeneration have shown that tree diameter and age are important determinants of the sprouting capacity of oaks and other hardwoods. Additional factors, especially those addressed by forest management strategies such as stand density and structure; affect the long-term survival of regeneration. Unfortunately, the models based on these relationships do not take into consideration the effects of Armillaria root disease on the successful survival of stump sprout regeneration on decline-prone sites. These relationships clearly need to be evaluated in order to develop models of stump sprout production and survival in declining vs. healthy stands.

The overall objective of this study is to assess, explain, and model the impact of Armillaria root disease on oak stump sprout regeneration in upland oak forests of the Ozark Mountains, where oak decline is most prevalent. This study will accomplish these objectives by building on a previous study of 701 oak stumps created during the first MOFEP (Missouri Ozark Forest Ecosystem Project) study harvest in 1996-1997.

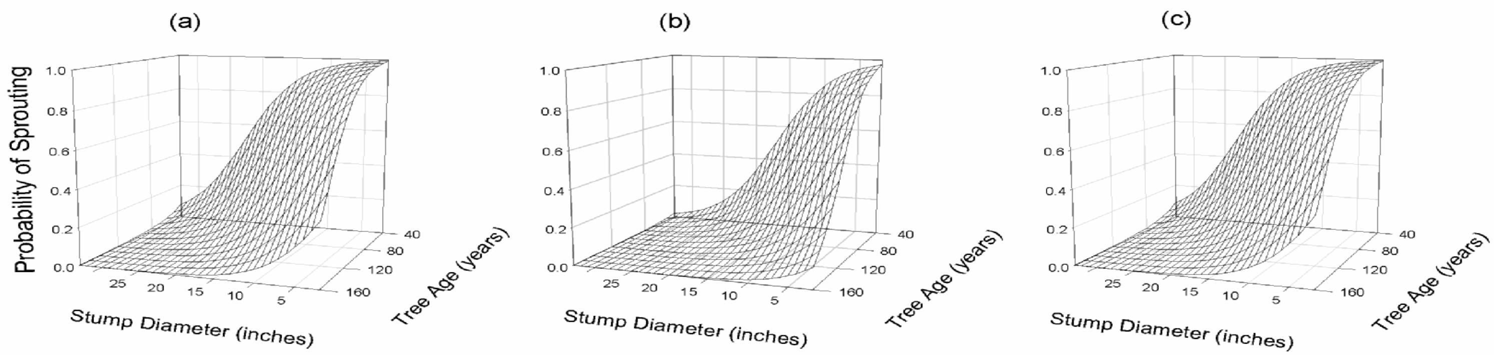

Figure 1. Probability of producing at least one live sprout at the end of the first growing season in relation to stump diameter and tree age for (a) black oak, (b) white oak and (c) scarlet oak. Plots are based on equations presented in Equation (1). Metric conversion is 1 inch = 2.54 cm.

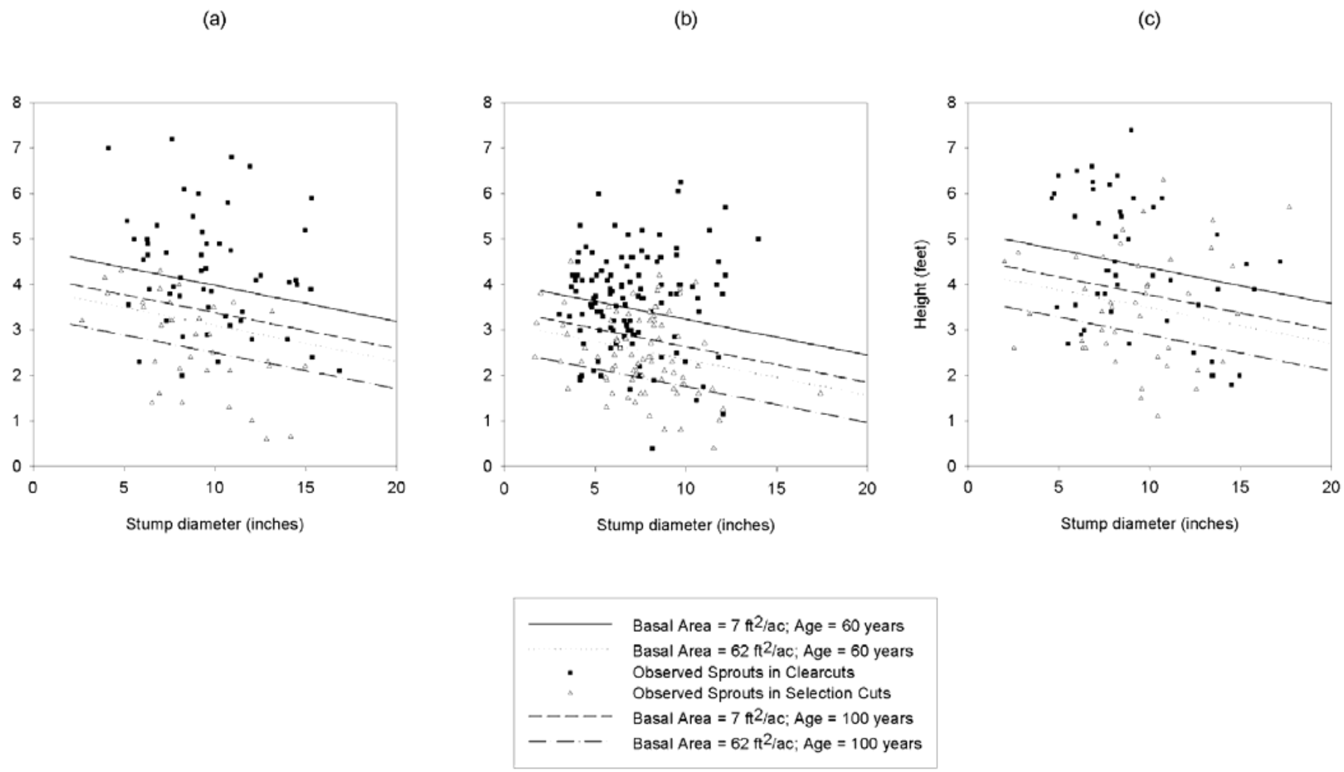

Figure 2. First-year height of the dominant stump sprout for (a) black oak, (b) white oak and (c) scarlet oak in relation to stump diameter, tree age and overstory density. Plotted lines are based on the equations presented in Table 4. Metric conversions are 1 inch = 2.54 cm; 1 foot = 0.3048 m; 1 $ft^2/ac = 0.2296\ m^2/ha$.

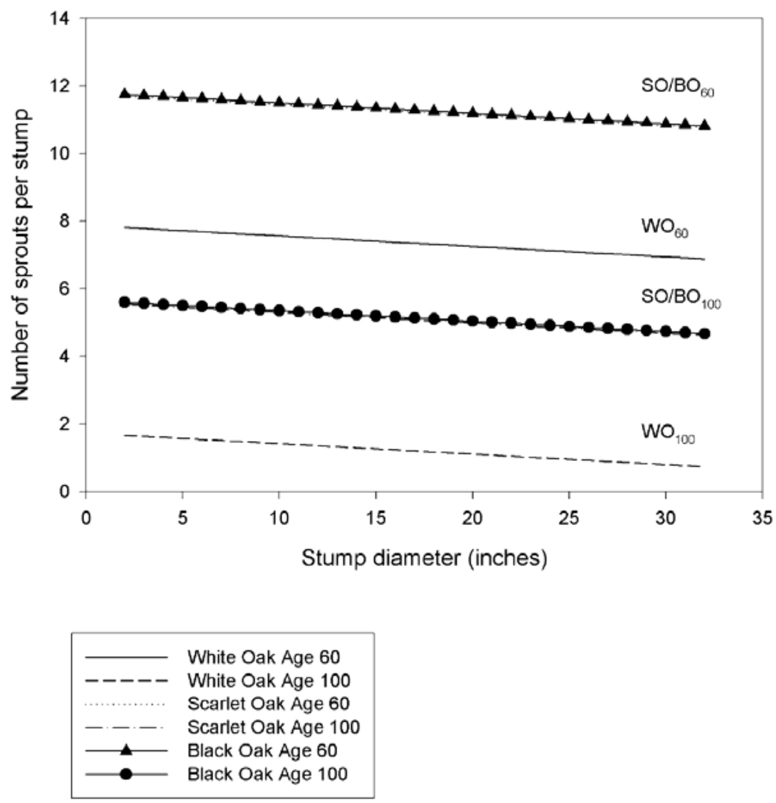

Figure 3. Predicted sprout clump density one year after harvesting by stump diameter and for selected ages of scarlet oak, black oak and white oak. Plots are based on Equation (2). Metric conversion is 1 inch = 2.54 cm.

Data Management

Team Members: Julie Fleming, Tom Treiman

As a MOFEP researcher you are aware that MOFEP is a long term, multi-disciplinary project. In order to help your own efforts and those of your colleagues, present and future, it is vital that all MOFEP data be archived in one central location and that it be well documented so that you and your colleagues can find and understand it today and in 100 years. The ability to integrate data from many years of related studies will be of great value to future researchers. Submitting data and metadata is also a requirement of all MOFEP contracts and grants!

A considerable amount of information has been submitted to the MOFEP web site already. The original MOFEP design included 23 projects. Two of these projects do not have project leaders/primary investigators assigned, and the projects have not moved forward. Nineteen of the remaining projects have submitted at least some data to the web site. There are 225 datasets from 69 studies that have been uploaded. In addition to the datasets, 56 maps and 168 publications have been uploaded.

There is more data available that still needs to be submitted to the website. For example, there are some datasets that have been described (i.e., the metadata has been entered) but not uploaded. There are also two projects that do not have any data submitted, but do have publications that have been uploaded. It is important that all of the information that has been collected be submitted to the web site.

If you have not logged on to the MOFEP web site recently, you may not be aware of some improvements to the metadata/data upload process. Our programmer has been working to streamline this process, and as a result entering your information is easier than it has been previously. The main MOFEP page is at http://mofep.mdc.state.mo.us and the metadata and data upload page can be reached by clicking on the "Metadata and Data Upload" link on the left side of the main page. The metadata and data upload page can also be reached directly at http://mofep.mdc.state.mo.us/app_login.asp .

This past year the MOFEP steering committee finalized the Guidelines for Access to MOFEP Data. These Guidelines explain the procedures for obtaining access to the data generated by the MOFEP projects. The Guidelines are available on the MOFEP website, at http://mofep.mdc.state.mo.us/guidelines.htm .

Landscape Modeling

Project Title: Using Missouri Ozark Forest Ecosystem Project data to add value to external research studies: examples for statewide cavity tree estimation, coarse woody debris estimation, and forest planning

Team Members: Stephen R. Shifley, Zaofei Fan, Frank R. Thompson III, William Dijak, David R. Larson, Josh Millspaugh, Michael Larson, Martin Spetich, John Kabrick, Randy Jensen, Brian Brookshire, Laura (Herbeck) Brookshire

Project Objectives:
These projects are neither funded by nor strictly tied to MOFEP. However, data from MOFEP have been essential to the successful completion of these projects. These are three examples of how past work on MOFEP has added significant value to other studies.

(1) Develop a system of models useful for estimating cavity tree abundance at stand, tree, and landscape scales. The models were developed from cavity tree data from across Missouri (FIA circa 1989), but were independently tested with cavity tree data from MOFEP. Data from MOFEP were also useful for understanding how the variance of the mean cavity tree abundance for a landscape decreases with increasing landscape size.

(2) Quantify the abundance and variability in the volume of coarse wood debris for forests of different ages and model how coarse woody debris volume changes along a regional gradient of increasing forest productivity.

(3) Develop the ability to model and forecast landscape-scale change in forest vegetation size structure and species composition in a spatially explicit manner. Use this capability as a tool to simultaneously forecast changes in trees, timber, and wildlife habitat suitability for forest landscapes up to 75,000 ha in size. Progress has been greatly enhanced by the availability of MOFEP woody vegetation data and associated GIS data layers.

Key Findings:
We modeled cavity tree abundance on a landscape as a function of forest stand age classes and as a function of aggregate stand size classes. We explored the impact of five timber harvest regimes on cavity tree abundance on a 3,261 ha landscape in southeast Missouri, USA, by linking the stand level cavity tree distribution model to the landscape age structure simulated by the LANDIS model. Over 100 years, mean cavity tree density increased constantly under all timber harvest regimes except for even-aged intensive management. This was due in large part to the continued maturation of the numerous stands that were > 70 years old at the start of the simulations. However, compared to the no harvest (control) regime, the uneven-aged, the mixed, the even-aged long rotation, and the even-aged intensive harvest regimes reduced the cavity tree density by 9-11, 11-13, 15-18, and 28-34 %, respectively, as more old stands were cut.

Cavity tree density (CTD) is an important indicator of habitat quality for cavity dependent wildlife. However, the abundance of cavities and cavity trees can vary dramatically, even among trees or stands with similar attributes. This uncertainty can make it difficult to expand stand level estimates of cavity abundance to large landscapes, although it is often desirable to do so. This limits the utility of CTD as a measure of habitat quality. We used a resampling method (statistical bootstrap) to construct a set of regression models to predict CTD based on landscape age structure and landscape size. We tested the regression models using an independent data set from the Missouri Ozark Forest Ecosystem Project (MOFEP) and found that the mean relative error (RE) when predicting CTD for landscapes between 300 and 4000 ha was less than 10%. Both the size (ha) of the landscape and the stand age class composition affected RE; but RE decreased with increasing landscape size in a consistent and quantifiable manner. For Ozark landscapes > 100 ha in size, knowledge of the proportion of the area in the seedling/sapling, pole, sawtimber, and old-growth age classes can be used to readily estimate the number of cavity trees and how that number will change if the landscape age structure is altered.

We measured 5 remnant old-growth hardwood tracts and 6 mature, second-growth, hardwood tracts in Missouri and compared findings concerning (1) the volume of down wood and (2) the number and size distribution of snags (i.e., standing dead trees). Volume of down wood ≥ 10 cm in diameter averaged 36 m3/ha on the old-growth tracts, double the 18 m3/ha mean volume for the second-growth sites. This difference in volume was concentrated in pieces of down wood with diameters larger than 20 cm; below diameters of 20 cm the number of pieces of down wood by diameter class was similar for the old-growth and second-growth sites. On the old-growth sites, the mean basal area of snags ≥ 10 cm dbh was 1.9 m2/ha. This was approximately 1.5 times greater than the mean basal area of snags on the second-growth sites. The number of snags ≥ 10 cm dbh on the old growth sites was approximately 9 percent of the number of live trees on those sites. The corresponding value for second-growth sites was 8 percent. On both the old-growth and second-growth sites, the number of snags and the number of live trees by dbh class followed a negative exponential (reverse-J) form. Frequency distributions for the number of snags by dbh class closely followed those for live trees on the same sites. These results provide managers with general guidelines for the quantity of down wood likely to be found in mature second-growth forests and old-growth forests.

Mean volume of standing dead trees across all old-growth sites was 21.4 cubic m/ha and down wood was 60.4 cubic m/ha. Both standing and down wood volume (total deadwood) increased along a regional gradient of increasing productivity from southwest Missouri to northeast Indiana and also increased with increasing age of dominant and codominant trees. Old-growth forests on high productivity sites averaged more pieces/ha of down wood in all diameter classes and higher volume/ha of down wood in nearly all diameter classes than did old-growth forests on low productivity sites. A chronosequence of forests from 10 years to > 200 years since stand establishment indicated a sharply declining down wood volume from age 10 to 70 years followed by increasing volume between 80 and 200 years.

We used a spatially explicit landscape model, LANDIS, to simulate the effects of five management alternatives on a 3,216 ha forest landscape in southeast Missouri, USA. We compared management alternatives for two intensities of even-aged management with clearcutting, uneven-aged management with group selection harvest, a mixture of even- and uneven-aged management, and no harvesting. Anticipated disturbances by windthrow and wildfire were included in the 100-yr simulations. The uneven-aged, even-aged long rotation, and mixed harvest regimes were similar to one another in total area in each forest size class, timber volume produced, and volume of wood on the forest floor. However, they varied greatly in quantity of edge habitat and in the extent of the mature forest habitat free from edge effects. The intensive even-aged harvest regime and the no-harvest regime produced the greatest volume of timber and the greatest volume of down wood, respectively. This model provides a quantitative framework to simultaneously explore multiple factors that affect landscape-scale management decisions.

Simulation models such as LANDIS allow comparison of the effects of forest management decisions and natural disturbance (i.e., wind and fire) on vegetation characteristics at large spatial scales. Habitat suitability and population viability models can be used to quantify the impact of those effects on wildlife populations. We evaluated differences among scenarios using GIS-based habitat suitability models we developed for a variety of terrestrial vertebrate species. Habitat characteristics in the models were primarily based on variables associated with tree species, tree age, and ecological land type. The habitat models also accounted for large-scale spatial patterns, such as patch-size and edge effects. We also evaluated differences among the forest management scenarios using a habitat-based population viability (RAMAS) model for ovenbirds (Seiurus aurocapillus). The combination of landscape vegetation simulation, spatially explicit habitat relationship models, and population viability analysis in a GIS allows dynamic evaluation of habitat quality and associated demographic impacts on wildlife populations across large spatial and temporal extents. This approach provides comprehensive information upon which to base decisions about alternative forest management options.

Scientific Outputs:

Publications

Shifley, S. R., Roovers, L. M., and B. L. Brookshire. 1995. Structural and compositional differences between old-growth and mature second-growth forests in the Missouri Ozarks. pp 23-36. In K. W. Gottschalk and S. L. C. Fosbroke (eds.). 10th Central Hardwood Forest Conference Proceedings, March 5-8, Morgantown WV. General Technical Report NE-197. U.S. Department of Agriculture Forest Service, Northeastern Forest Experiment Station, Radnor P.A. 577p. (Refereed)

Brookshire, B. L., and Shifley, S. R.(eds.). 1997. Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. General Technical Report. NC-193. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, MN. 378p.

Kabrick, J. M.; Larsen, D. R.; Shifley, S. R. 1997. Analysis of pretreatment woody vegetation and environmental data for the Missouri Ozark Forest Ecosystem Project. p. 150-168 In: Brookshire, B. L.; Shifley, S. R. (eds.). Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research. 1997 June 3-5; St. Louis, MO. General Technical Report. NC-193. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, MN. 378p.

Shifley, S. R., B. L. Brookshire, D. R. Larsen, and L. A. Herbeck. 1997. Snags and down wood in Missouri old-growth and mature second-growth forests. Northern Journal of Applied Forestry 14 (4):165-172. (Refereed)

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Shifley, S. R. and J. M. Kabrick (eds.) 2002. Proceedings of the second Missouri Ozark Forest Ecosystem Symposium: post treatment results of the landscape experiment. October 17-20, 2000; St. Louis, MO. General Technical Report. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 228p.

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Shifley, Stephen R.; Thompson, Frank R., III; Dijak, William D. 2003. Simulating effects of timber management, wind, and fire on forest landscapes to guide multiple-use forest planning. Book of abstracts. In: IUFRO. Decision support for multiple purpose forestry: a trans disciplinary conference on the development and application of decision support tools for forest management; 2003 April 23-25; Vienna, Austria [City, Country: Publisher unknown]: 36. Abstract.

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Michael A. Larson, Frank R. Thompson III, Joshua J. Millspaugh, William D. Dijak and Stephen R. Shifley. 2004. Linking population viability, habitat suitability, and landscape simulation models for conservation planning. Ecological Modelling 180(1):103-118.

Invited Presentations

Shifley, S. R. 1994. Snags and down wood in old-growth and mature second-growth upland forests in Missouri. Missouri Department of Conservation, Missouri Forest Ecosystem Project Meeting, Jefferson City, MO. November 17, 1994. (Abstract)

Shifley, S. R. 1995. Snags and down wood in old-growth and mature second-growth upland forests in Missouri. Natural Areas Conference, Fayetteville, AR. Oct 25-28, 1995. (Abstract)

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Shifley, S. R. 1999. Modeling forest change over time. Indiana Society of American Foresters Winter Meeting, Indianapolis, IN. February 24, 1999.

Kabrick, J. M., R.G. Jensen, D. R. Larsen, and S.R. Shifley. 2000. Effects of even-aged, uneven-aged, and no-harvest management on woody vegetation at the Missouri Ozark Forest Ecosystem Project. Natural Areas Conference. St, Louis, MO. October 18, 2000.

Offered Presentations

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Future Plans:
We intend to continue to work with Mark Twain National Forest on large scale simulation of overstory vegetation and wildlife habitat as affected by alternative harvest methods and natural disturbance scenarios.

Tick-Borne Disease

Project Title: The effect of forestry practices on human risk of tick-borne disease

Team Members: Brian F. Allan, Jonathan M. Chase, Richard S. Ostfeld and Gregory A. Storch

Project Background:
The incidence of vector-borne zoonotic diseases in humans is on the rise in North America, generating considerable public concern about the health risks associated with human interactions with wildlife and the outdoors. Until recently, the state of Missouri was considered to have relatively low incidence of tick-borne disease, with very few cases of Lyme disease or other tick-borne diseases reported. This changed with the recent emergence of a group of tick-borne bacteria in the genus *Ehrlichia*, several of which cause disease in humans, their pets, and wildlife. One increasingly common species is *Ehrlichia chaffeensis*, which causes human monocytic ehrlichiosis (HME), an emergent zoonotic disease in North America. The area of highest incidence of HME in the United States occurs in southeastern Missouri, making MOFEP an ideal location to study the potential interaction between human land use and the ecology of this emerging pathogen.

There are multiple mechanisms by which forestry practices could affect the abundance of disease-causing *Ehrlichia* species in natural ecosystems. The primary reservoir for *E. chaffeensis* is the white-tailed deer, a ubiquitous large mammal in North America and a dominant community member in disturbed and fragmented habitats. In particular, white-tailed deer are edge-specialists, so forestry practices that increase the ratio of forest-edge to interior are likely to increase their abundances. Other potential wildlife reservoirs for *E. chaffeensis* include red foxes, raccoons, opossums, small mammals and ground-dwelling birds such as turkeys. Many or all of these species are likely to be affected by forestry practices. The primary vector of *E. chaffeensis* is the lone star tick (*Amblyomma americanum*), although the dog tick (*Dermacentor variabilis*) is also capable of transmission. Both are forest-dwelling species capable of parasitizing a wide-range of hosts, and so forestry practices could alter the distribution and abundance of these tick species directly through changes in habitat necessary for off-host survival and/or indirectly through changes in host abundance. Therefore, through changes in tick and tick-host abundance and diversity, forestry practices could influence the density and infection prevalence of tick vectors for *E. chaffeensis*, the etiological agent of HME.

To determine if a relationship between forestry practice and risk of tick-borne disease exists, we measured the density of infected ticks in the MOFEP compartments. The density of infected ticks is the best ecological measure of human risk, because it estimates a person's probability of encountering an infected tick while in tick habitat. Using standard tick survey methodology, we dragged a one-meter square drag-cloth along the ground over four, 100-meter transects in each of the nine MOFEP compartments, stopping every 20 meters to remove ticks that attached to the cloth. The number of ticks collected was divided by the distance dragged to provide an estimate of tick density. Collected ticks were stored in ethanol and brought back to Washington University where they will be tested for pathogens using PCR.

Key Findings:

Our surveys of tick densities during the June peak in nymphal tick abundance supported the hypothesis that forestry practice could impact human disease risk. Even-aged treatments had higher densities of nymphal ticks (0.11 nymphs/m^2) than did uneven-aged treatments (0.07 nymphs/m^2), and both treatments had higher densities of nymphal ticks than did control areas (0.02 nymphs/m^2) (ANOVA, R^2 = 0.89, P = 0.037). While pathogen testing is still in progress, the potential exists for increased disease risk mediated via increases in tick abundance due to forestry practice alone. Additional surveys were conducted in August during the peak in larval tick abundance in order to address the question of whether different nymphal abundances are directly a result of distributions of the larval life stage. While not statistically significant, the results of this survey were consistent with the effect of forestry practice on nymphal tick densities. Even-aged treatments had higher densities of larval ticks (2.9 larvae/m^2) than did uneven-aged treatments (2.3 larvae/m^2), and both treatments had higher densities of larval ticks than did control areas (1.6 larvae/m^2) (ANOVA, R^2 = 0.88, P = 0.18). Deer dung surveys, as an estimate of deer abundance, were conducted along the same transects in August to determine whether our results with tick density was correlated with variation in deer abundance. While also not statistically significant, the abundance of deer in relation to forestry practice was weakly consistent with the trend for tick densities, with even-aged treatments having higher deer abundance (0.013 dung clusters/m^2) than uneven-aged treatments (0.006 dung clusters/m^2) or control areas (0.005 dung clusters/m^2) (ANOVA, R^2 = 0.77, P = 0.17). In future years, we will increase sampling effort, which we expect will give us more power to discern these patterns.

Conclusion:

In conclusion, our initial results support the hypothesis that forestry practice can impact human risk of exposure to tick-borne diseases in southern Missouri. Further field work will be required to determine if the effect of forestry practice on the densities of ticks is consistent across all tick life stages. Our future work with also include surveys of other major tick hosts, particularly turkeys, which will be important in formulating a picture of the response of the entire tick-host community to forestry practice. Finally, extensive laboratory testing will be necessary to determine if there is a relationship between forestry practice and tick infection prevalence.

Water Quality

Project Title: Evaluating timber harvesting effects on water quality in low-order streams in the Missouri Ozarks

Team Members: John J. Bowders, Ryan P. Mueller, David Gwaze, and W. Keith Moser

Project Background:
The Missouri Ozarks, like many other underdeveloped and sparsely-populated areas of the country, has undergone several significant changes in landuse. Many acres of low value hardwood timber land have been cleared and converted to pasture by an increasing number of private cattle speculators (Settergren, 1972). Chip mills can provide a market for low-quality timbers thinned from current hardwood stands; some landowners practiced large-scale complete removals and, often, site conversions to pasture. With the second growth oak-hickory and pine forests rapidly reaching commercial maturity, several relatively large blocks of land have been opened through clearcutting (Settergren, 1972).

Nearly every state with significant commercial forest operations, including Missouri, has Best Management Practices (BMPs) to protect water quality (Ice *et al*. 1997). Operational experiences suggest that timber harvesting conducted in accordance with BMPs does not have a long-term deleterious effect on stream ecosystems, but there have been few quantitative studies of harvesting and water quality. The Ozark region has no long-term, instrumental record of hydrologic, water quality and sediment impacts at the scales of operable timber harvests.

An understanding of the physical and chemical processes in ephemeral streams adjacent to harvested areas is critical to developing management guidelines for private and public landowners that provides protection for the biodiversity of the stream ecosystem. This project will not only test the efficacy of current BMPs, but will also provide the foundation to further examine harvesting effects on species richness and competitive ability in sites where active forest management occurs.

Physical Setting and Site Selection:
Fifteen sites have been selected for this study. All sites are located on forested land managed by the Missouri Department of Conservation (MDC) within the Angeline and Current River conservation areas (Figure 1) in Missouri, USA. The prevalent secondary growth hardwood forests are situated within the Interior Highlands of the oak-hickory region. Precipitation averages approximately 115 cm annually with an average of 22 percent of the total in annual runoff (Settergren, 1986).

Figure 1. Study Area, Shannon and Reynolds Counties, Missouri, USA

The study area lies in the Current River drainage basin within the Ozark Highlands and is characterized by rugged, deeply dissected lands with topographic relief ranging from 45 to 150 m. Study sites are restricted to small upland headwater watersheds where timber quality and yield is generally considered to be the highest within the landscape. All sites are located on low-order, ephemeral streams (according to Strahler 1952). Study site areas range from 6 to 15 hectares with planned harvest areas ranging from 3 to 7 hectares. A typical study site is illustrated in Figure 2.

The regional geology consists of horizontally bedded dolomite and sandstone bedrock units. All materials within this thick sequence of carbonate rocks are soluble and create karst topography, including some very large springs and caverns, sinkholes, and dry valleys (Nigh and Schroeder, 2002). Stream flow in upland ephemeral channels generally occurs only during intense precipitation events. Surficial materials are clayey with numerous rock fragments, chiefly insoluble chert left behind as the carbonate rocks are dissolved. Soils are closely related to bedrock lithology and landscape position. Soils formed in bedrock residuum are typically low in soluble bases such as calcium and magnesium and may contain a root-restricting fragipan in the subsoil (Nigh and Schroeder, 2002). A thin veneer of hillslope sediments (reworked loess) may exist throughout the landscape.

Instrumentation and Monitoring Plan:
During the study ten sites will be harvested while five will remain as unharvested control sites. All sites will be either “intensively” or “extensively” monitored. Four intensively monitored sites are instrumented with a combination of automated and manual devices including:

- ISCO® water samplers (automated);
- sediment traps;
- rising gauge water samplers;

- rain gauges; and,
- stream crest gauges.

Figure 2. A typical study site located within an upland headwater watershed

For intensive monitoring, four sites are located in close proximity on similar landforms and soils. For extensive monitoring, four sites will be co-located on the intensive sites to provide a correlative relationship between the intensive and extensive methodologies, while the remaining eleven sites will be located on similar watersheds throughout the study area. The eleven extensively monitored sites are instrumented entirely with manual instrumentation and are intended to collect "coarse" data for validation of results from intensively monitored sites.

ISCO® and/or rising gauge water samplers are installed in ephemeral stream channels in upstream and downstream monitoring locations with respect to harvest plots.
As the water rises the sample bottles fill when the water level reaches the height of the inlet tubes. Samples are thus taken just below the surface of the water. In addition to these devices, simple crest gauges will be utilized to estimate the maximum gauge height and discharge rate of ephemeral streams. Sediment traps installed on side slopes will provide a measure of sedimentation, sediment composition, and overland flow. Each trap or "plot" is approximately 1.25 m wide and 3 m long, with the long axis oriented with the slope of the site. The top and sides of the plot are bordered with aluminum flashing placed in filled trenches in the ground to a depth of approximately 10 cm. The flashing prevents surface flow originating from outside of the plot being collected. Surface flow from inside the plot will be collected in a trough at the lower end and diverted through a debris filter into a catchment for measurement and sample collection. Runoff and

sediment accumulation will be calculated by measuring the volume of water/solids accumulated in the catchment. Sediment trap plots will also be used to sample the aspect, soil series, percent cover and composition of the cover (leaves, rocks, vegetation, coarse woody debris) during the study. Each sediment trap will be instrumented with a rain gauge to measure throughfall. The sediment trap and associated equipment is shown in Figure 3. The rising gauge water sampler is shown in Figure 4. A schematic of a typical instrumentation layout for an extensively monitored site is shown if Figure 5.

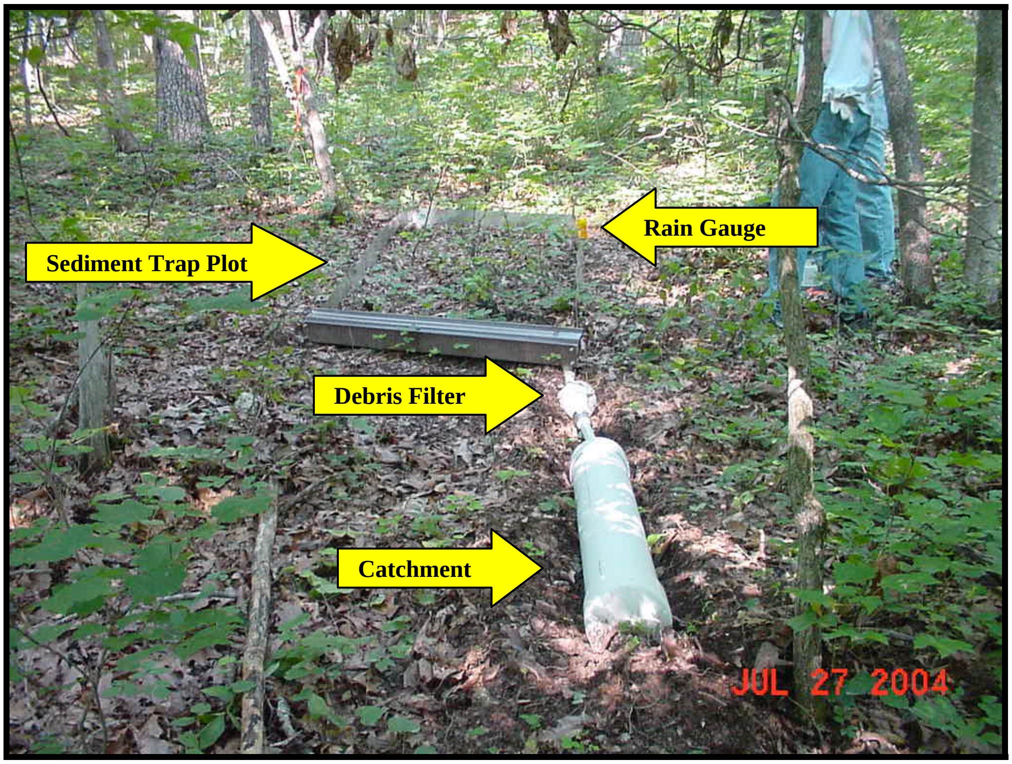

Figure 3. A sediment trap installed on a side slope

Figure 4. A rising gauge water sampler installed in an ephemeral channel

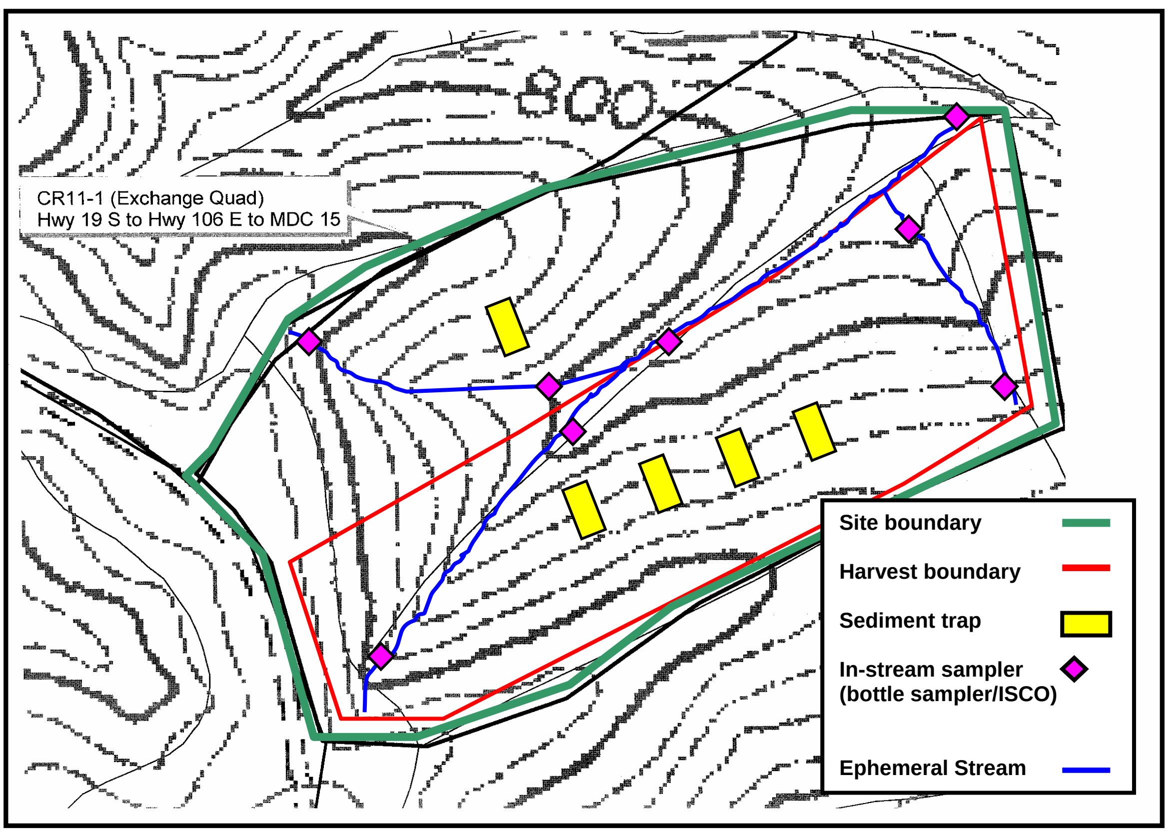

Figure 5. Site instrumentation layout of an extensively monitored site

Testing, Analysis and Anticipated Results:
Monitoring of sediment and water quality will be performed for one to three years prior to timber harvest in order to quantify the baseline variability in measured parameters. The parameters to be monitored include: total nitrogen, suspended solids, nitrogen (NH_4^+, NO_3^-), cations (Ca^{2+}, Mg^{2+}), nutrients (K, P), conductivity and pH. Pre-harvest baseline monitoring duration is a function of the programmed timber harvest cycle. Sites programmed for harvest further in the future will have a longer baseline period. All five non-harvested sites will provide long-term baseline data.

The pre-harvest data provides an opportunity to quantify the behavior of the sediment and water quality parameters as a function of season, precipitation intensity, vegetation, density, site slope and aspect and will be evaluated for correlations. In addition, pre-harvest data will be used to compare in-stream results to hill-slope sediment trap results. Findings from the intensively instrumented sites will be compared with those from the extensively instrumented sites. Post-harvest data will be evaluated in light of both the pre-harvest results and the on-going results from the five control sites.

Conclusions:
Water quality is influenced by healthy forests. State BMPs derive at least part of their purpose from the desire to protect stream ecosystems from anthropogenic influences such as timber harvesting. Missouri will better fulfill its mission of protecting State resources and addressing public concerns if it can demonstrate that it has examined the impacts of timber harvesting and taken appropriate action. This research is important to ascertain the cause and effect relationships of harvesting upon water quality at the local level and is the first step in determining if further study and/or modification of the BMPs is necessary.

Acknowledgements:
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Harvest impacts

Project Title: The impacts of the 1996 harvest on MOFEP treatment plots

Project Team: John Dwyer

Project objectives:
The primary objective of this project was to summarize postharvest logging impact data following the 1996 harvest of MOFEP sites and to determine to what extent skidding and felling activities had on the different silvicultural treatments.

Key Findings:
Although damage levels to bole and crown of leave trees was low for all treatments, the individual tree selection (uneven-aged) treatment did show:

(1) higher levels of surface area skidder impact;
(2) higher percentage of leave trees with one or more bole wounds;
(3) higher number of bole wounds;
(4) higher percentage of wounded trees in the dominant and co-dominant crown class;
(5) and the highest percentage of leave trees impacted by logging activity.

Scientific Output:
Pre-harvest planning that involves skid trail layout and discussion with the skidder operator(s) will reduce the area impacted by skidding to less than 12%. Also, the probability of a bole wound to a residual tree can be reduced to less than 5% if skid trails are kept 30 feet or more from the leave tree. Good sale administration involves the active participation of the logger and forester on a regular basis in order to prevent poor logging practices.

Research Plans for 2004/2005:
The NJAF is publishing the results of this study in their 21(4) 2004 issue. This manuscript was accepted in June, 2003 but lost in the system until just recently. At this point in time we have no plans to conduct research into harvest impacts.

Integration study

Project Title: MOFEP Integration study

Project Team: Wendy Gram

Project objectives:
To rigorously evaluate the effectiveness of forest management treatments for Missouri Ozark forests, we must examine treatment effects at a variety of temporal, spatial, and ecological scales. The main objective of this study is to integrate MOFEP data from multiple MOFEP studies across different spatial and temporal scales to evaluate the effects of the experimental treatments. Multidisciplinary analyses can potentially identify large-scale patterns among taxa and environmental characteristics that will help us understand how and why forest management treatments affect species. As a part of this objective, we are also documenting spatial and temporal variation in diversity and abundance of organisms and ecosystem elements. Integration of MOFEP data encourages collaboration among principle investigators which is likely to yield both additional insights into interpretation of results and novel ideas for future management and research activities. This integration also helps identify shortcomings in data collection and scale-issues for the MOFEP community to address as research continues.

Since 1997, we have addressed a variety of specific research questions across multiple MOFEP studies. Our first study synthesized pre-treatment MOFEP data for the first MOFEP symposium and GTR. From 1998 to 2001, we analyzed data from the tree genetic, overstory, ground flora, geolandform, and bird studies to address questions about environmental correlates of diversity, abundance, and genetic structure in Missouri Ozark forests. From 2002 to the present, we have focused on evaluating post-treatment effects at a variety of ecological, spatial and temporal scales.

Key Findings:
Pre-treatment Analyses

- Synthesizing pre-treatment data from 12 MOFEP studies, we found few pre-treatment effects (i.e., differences among proposed treatment areas), but data from block 3 were frequently different than blocks 1 and 2. Correlations among the density/abundance of 24 species from seven different taxonomic groups yielded 25 significant relationships, suggesting that it is important to integrate data among taxa to identify relationships that potentially influence widespread ecosystem processes.
- Based on genetic and demographic data from *Quercus alba*, *Carya tomentosa*, and *Sassafras albidum*, genetic variation is correlated with environmental heterogeneity but not related to soil type/aspect classes, suggesting that genotypic differentiation is operating on a finer scale than soil or aspect differences.
- Based on genetic and demographic data from *Quercus alba*, *Carya tomentosa*, and *Sassafras albidum*, population density is not correlated with genetic diversity in large populations of plant species, but density is associated with genotypic composition of populations. That is, populations with small densities had

different genotypes than those with large densities. Population density may be a useful rule of thumb for conservation practitioners concerned with the maintenance of adaptive genetic variation in plant species.

Post-treatment Analyses

- In the short term (2 years of post-treatment data), even-aged and uneven-aged forest management treatments caused changes in animal community densities relative to no-harvest management. Even-aged management sites showed greater changes than uneven-aged management sites after harvesting, and changes in species' densities were larger two years post-treatment than one year post-treatment.
- At the community level, coarse measures and indices of community diversity (i.e., species diversity, evenness, species richness) were generally not informative and masked important differences among treatments and study sites.
- For reptiles and amphibian species, even- and uneven-aged forest management treatments significantly affected abundance of *Bufo americanus* in the MOFEP area. This species declined less on even-aged management sites than on no-harvest sites, but the general decline on all sites suggests that other factors may have contributed to this result. Within even-aged management sites, most amphibian species declined and some reptile species increased relative to pre-treatment abundances within clearcut stands. We conclude that clearcuts within even-aged management sites locally affected amphibian and reptile species but, at a larger spatial scale, we did not detect significant effects of forest management treatments.
- Densities of mature forest bird species declined 24-69% on no-harvest sites during post-treatment years (1997-1999). Densities of two of five mature forest species increased in even-aged and uneven-aged management sites post-treatment whereas density of one species decreased on even-aged management sites. Treatment significantly and positively affected density of four of the six early successional bird species.
- Timber harvest treatments may have affected forest bird densities on no-harvest sites.

Research Plan for 2004-2005:

We are working on the following research questions this year:

- What issues are associated with integrating MOFEP data? Specifically, what types of data are missing, what data can and cannot be integrated with other MOFEP data, what data is not accessible or useable in its current format, what changes could help alleviate obstacles to integration?
- Is community-level animal diversity (i.e., species richness, evenness, and abundance/density) different on MOFEP sites 5 – 8 years post-treatment than during pre-treatment years?
- Is the relationship between bird density and caterpillar density different during pre-treatment years than post-treatment years?

This study relies on existing MOFEP data collected from 1991 – 2003. Our approach includes the following components:

1. Data acquisition from appropriate MOFEP PI and data management
2. Preliminary data assessment to identify nature of data and potential trends
3. Data analysis based on specific research questions and data format
4. Synthesis of results
5. Preparation of manuscripts and presentations based on results

Scientific Outputs:

Publications

Renken, R. B., W. K. Gram, D. K. Fantz, S. C. Richter, T. J. Miller, K. B. Ricke, B. Russell, and X. Wang. 2004. Effects of forest management on amphibians and reptiles in Missouri Ozark forests. Conservation Biology 18(1):174-188 .

Gram, W. K., P. A. Porneluzi, R. L. Clawson, J. Faaborg and S. C. Richter. 2003. Effects of forest management on the density and nesting success of bird species in Missouri Ozark forests. Conservation Biology 17(5): 1324-1337.

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Gram, W. K., V. L. Sork, R. J. Marquis, R. B. Renken, R. L. Clawson, J. Faaborg, D. K. Fantz, J. LeCorff, J. Lill and P. A. Porneluzi. 2001. Evaluating the effects of ecosystem management: a case study in a Missouri Ozark Forest. Ecological Applications 11(6): 1667-1679.

Gram, W. K., and V.L. Sork. 2001. Association between environmental and genetic heterogeneity in forest tree populations. Ecology 82(7): 2012-2021.

Gram, W. K., and V. L. Sork. 1999. Population density as a predictor of genetic variation for woody plant species. Conservation Biology 13(5): 1079-1087.

Gram, W. K., V. Sork, and R. Marquis. 1997. Synthesis and integration of pre-treatment results from the Missouri Ozark Forest Ecosystem Project (MOFEP). Pages 356-396 in B. L. Brookshire and S. R. Shifley, editors. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: an experimental approach to landscape research. General Technical Report NC-193, U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, MN.

Invited presentations

Gram, W. K. Effects of landscape-level disturbance on community structure in Missouri Ozark forests. University of Oklahoma, Department of Zoology seminar series, September 2000.

Gram, W. K. Effects of landscape-level disturbance on animal communities. State University of New York -Syracuse, College of Environmental Science and Forestry seminar series, October 1999.

Gram, W. K. Effects of landscape-level disturbance on communities in Missouri Ozark forests. Dartmouth College, Department of Biological Sciences seminar series, April 1999.

Gram, W. K., and V.L. Sork. Missouri Ozark Forest Ecosystem Project (MOFEP): A collaborative experiment examining impact of forest management on ecosystem integrity. In the symposium "Intersection of diverse perspectives: Results from creative cross-disciplinary collaborations" at Ecological Society of America annual meeting, Baltimore, MD, August 1998.

Presentations at professional meetings

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